

# GLOBAL NUCLEAR ENERGY PARTNERSHIP

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## HEARING BEFORE THE COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE ONE HUNDRED TENTH CONGRESS

FIRST SESSION

TO

RECEIVE TESTIMONY ON THE GLOBAL NUCLEAR ENERGY PARTNER-  
SHIP AS IT RELATES TO U.S. POLICY ON NUCLEAR FUEL MANAGE-  
MENT

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NOVEMBER 14, 2007



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# CONTENTS

## STATEMENTS

	Page
Bingaman, Hon. Jeff, U.S. Senator From New Mexico .....	1
Bunn, Matthew, Belfer Center For Science and International Affairs, Harvard University, Cambridge, MA .....	26
Corker, Hon. Bob, U.S. Senator From Tennessee .....	56
Craig, Hon. Larry E., U.S. Senator From Idaho .....	54
Domenici, Hon. Pete V., U.S. Senator From New Mexico .....	3
Dorgan, Hon. Byron L., U.S. Senator From North Dakota .....	42
Orszag, Peter R., Congressional Budget Office .....	13
Salazar, Hon. Ken, U.S. Senator From Colorado .....	2
Seshadri, Pattabi, Partner and Managing Director, Boston Consulting Group, Boston, MA .....	43
Sessions, Hon. Jeff, U.S. Senator From Alabama .....	60
Spurgeon, Dennis, Assistant Secretary For Nuclear Energy, Department of Energy .....	5
Todreas, Neil E., Massachusetts Institute of Technology, Cambridge, MA .....	36
Wallace, Terry, Principal Associate Director, Science, Technology and Engi- neering, Los Alamos National Laboratory, Los Alamos, NM .....	21
Wyden, Hon. Ron, U.S. Senator From Oregon .....	59

## APPENDIXES

### APPENDIX I

Responses to additional questions .....	69
---	----

### APPENDIX II

Additional material submitted for the record .....	89
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## GLOBAL NUCLEAR ENERGY PARTNERSHIP

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WEDNESDAY, NOVEMBER 14, 2007

U.S. SENATE,  
COMMITTEE ON ENERGY AND NATURAL RESOURCES,  
*Washington, DC.*

The committee met, pursuant to notice, at 10 a.m. in room SD-366, Dirksen Senate Office Building, Hon. Jeff Bingaman, chairman, presiding.

### OPENING STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

The CHAIRMAN. Why don't we go ahead and open the hearing. This is a hearing on the Global Nuclear Energy Partnership. I want to thank the witnesses for being here.

The purpose of the hearing is to understand the Department of Energy's Global Nuclear Energy Partnership, or GNEP, both the policy involved in the decisions, and also the programmatic actions and viewpoints involved.

From 2000 to 2006, the Department conducted a research program which was the predecessor to GNEP, it was called the Advanced Fuel Cycle Initiative, or AFCI. This program performed research on spent fuel separations technologies that might make it possible to reduce the volume and heat load in a spent fuel geologic repository. The program had good support, and was authorized as a research, development and demonstration program, in the Energy Bill that was passed in 2005.

It's my understanding that there were promising bench-scale technologies, and that for Fiscal Year 2007, the program was expected to begin to scale up to a demonstration phase.

In light of that background, it was somewhat surprising when for Fiscal Year 2007, the GNEP program was proposed, with a budget nearly three times the size of the Advanced Fuel Cycle Initiative, or \$243 million, and the proposal was to begin engineering design of a spent fuel separations plant, a fast reactor and a fuel R&D facility—none of which were planned to come online until the 2020, or through 2030 timeframe.

The program seems to have undergone shifts since it was presented to Congress in February 2006, from deploying advanced separation technologies in the Advanced Fuel Cycle Initiative, to requests from industry for near-term technologies that primarily separate plutonium.

I'd like to learn what I can about the evolution of the program, and the impact it will have on our spent fuel policy.

The National Academies of Science recently evaluated the GNEP program. They are not here as witnesses today, but I will offer into the record the summary of their recommendations to reflect the hard work that their panel put in.

[The prepared statements of Senators Bingaman and Salazar follow:]

PREPARED STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

Let me open today's hearing on the Global Nuclear Energy Partnership by thanking the witnesses for taking the time today out of their busy schedules to testify.

The purpose of today's hearing is to understand the Department of Energy's Global Nuclear Energy Partnership or GNEP from both policy and programmatic viewpoints.

From 2000 to 2006, the Department conducted a research program, which was the predecessor to the GNEP program, called the Advanced Fuel Cycle Initiative or AFCI. This program performed research on spent fuel separations technologies that might make it possible to reduce the volume and heat load in a spent fuel geologic repository. The program had good support and was authorized as a research, development and demonstration program in the Energy Policy Act of 2005. It is my understanding there were promising bench scale technologies and that for Fiscal Year 2007 the program would begin to scale up to a demonstration phase.

Thus it came as a surprise when for Fiscal Year 2007, the GNEP program was proposed with a budget nearly three times the Advanced Fuel Cycle Initiative at \$243M by proposing to begin engineering design of a spent fuel separations plant, a fast reactor and a fuel R&D facility all not coming on line until the 2020-2030 timeframe.

The GNEP program seems to have undergone shifts since it was presented to the Congress in February 2006, from deploying advanced separation technologies in the Advanced Fuel Cycle Initiative to requests from industry for near-term technologies that primarily separate plutonium. I would like to learn about the evolution of the program and the impact it will have on our spent fuel policy.

The National Academies of Science recently evaluated the GNEP program and they are not at the witness table, let me offer into the record the summary of their recommendations to reflect their hard work.

Again, let me thank the witnesses for coming today and I look forward to learning from their testimony.

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PREPARED STATEMENT OF HON. KEN SALAZAR, U.S. SENATOR FROM COLORADO

Thank you Mr. Chairman and Ranking Member Domenici for holding today's oversight hearing on the Department of Energy's Global Nuclear Energy Partnership program. GNEP has significant policy implications for our national security and our nuclear energy industry, and today's hearing is an important opportunity to discuss these issues.

GNEP has been highly touted by this Administration as a route to a new era of proliferation-resistant nuclear energy usage. The program purports to close the nuclear fuel cycle and usher in a new generation of advanced nuclear reactors. GNEP also espouses the global expansion of nuclear power through an innovative partnership of fuel-producing and fuel-consuming nations, and it argues for a rapid and vast remaking of our domestic nuclear power industry.

These notions are radical departures from the strict, consistent U.S. nuclear policy of discouraging civilian nuclear fuel reprocessing of the last thirty-plus years. In 1974, the U.S. and the world were scalded when India conducted its first test of a nuclear weapon. President Eisenhower's "Atoms for Peace" program, which supported India's development of a civilian nuclear energy program, had led to a new nuclear state. Our lesson from that experience was clear: that the benefits of civilian nuclear programs and the risks of nuclear proliferation are tightly intertwined.

GNEP represents a sea-change from our traditional policy by explicitly promoting the expansion of nuclear power into developing countries around the world. For GNEP to accomplish its stated goals without also increasing the risk of nuclear proliferation is a tall order, and will hinge critically on the technological basis of the nuclear fuel program it develops.

I am deeply concerned that DOE is putting the cart before the horse by pushing policy decisions ahead of technical knowledge. By already placing great emphasis on one or two reprocessing techniques and advanced reactor designs, DOE is threat-

ening to undermine the determination of whether a truly proliferation-resistant closed nuclear fuel cycle can be developed. These technologies are still in an early stage, and talk of commercial-scale demonstration projects is woefully premature. A recent National Academies report confirms the deep concerns that other non-proliferation experts have recently expressed about GNEP.

Furthermore GNEP is expensive. If enacted as envisioned, it will be a multi-decade, multi-billion dollar commitment. Saying there is “healthy skepticism” about GNEP’s economic viability is probably an understatement. Studies by the National Academies, Harvard, and MIT suggest that reprocessing spent fuel will not become cost competitive with conventional interim dry cask storage of nuclear waste until at least 2050. Some have even argued that the diversion of our limited nuclear technical resources to insufficiently justified GNEP programs may itself pose a significant economic risk to the nuclear industry.

As it is currently constituted and expressed, GNEP poses significant risks. Development of a closed, proliferation-resistant nuclear fuel cycle is a laudable goal—if achieved it could potentially transform the future of global electric power generation. I look forward to learning today about our witnesses’ perspectives on the path that GNEP lays forward, and their opinions of whether GNEP is technologically and economically viable.

The CHAIRMAN. Again, I thank the witnesses for coming, and I yield to Senator Domenici for any opening statement he would have.

**STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM  
NEW MEXICO**

Senator DOMENICI. Thank you very much, Mr. Chairman. I’m glad we have some other Senators here. Nice to have you, Senator Martinez, and Senator Craig. This is one of the areas you have great interest in.

I have a rather long, detailed statement. My staff is going to be very upset because they worked very hard to prepare it, at my direction, last night. Instead, I’m going to try to tell you what bothers me about this hearing, and about where we are; but let that written statement be part of the record.

First of all, I think the problem with GNEP is that it’s a 50-year program, and the United States can’t wait 50 years for what we need. We need something that GNEP would provide us with, but it’s going to take way too long, and it has ingredients that are far too controversial for us to base the entire future of nuclear power on.

Now, it’s well thought out, it’s terrific. If you had all the money in the world, and if you could produce all of the technical machines that they’re talking about, it would be wonderful.

But, Mr. Chairman, what I’m looking for, and I hope in the not too distant future you can join me in trying to produce legislation for this, is the fastest method to proceed with the construction of a recycling facility in the United States. That’s sometimes called something else, but reprocessing is a word others use.

Now, what I’m talking about is not far-fetched, because they’ve already done it in Europe. The problem is, we don’t seem to like the technology they’ve used, the so-called PUREX, Mr. Chairman—because it produces a big, steady stream of pure plutonium. There has to be another technology, and it is very far along, and the product that comes out of it is not pure plutonium. It’s a mixture, and thus, passes the test that we, most American leaders would put on it, that we don’t want to promote the PUREX-type recycling.

So, much of what I will do is listen, but what I really want to know, as soon as I can get it, is how can America proceed from where we are to the authorization and evolution and building of a recycling plant? If one won't do it, than two, but to get on with that, as soon as possible, considering two issues that concern me.

First, the liability of the Federal Government, or potential liability that lies out there for its failure to remove spent fuel from reactor sites; and second, the fact that Yucca Mountain is getting more and more to look like a project that's not going to be used to put once-through spent fuel rods deeply underground. That idea has less and less credibility, and Yucca itself has less and less credibility. It can be used for something important, but we ought to decide rather quickly on what I've just iterated, and it is my hope that it is what we will proceed with.

So, the witnesses will help us immensely, as we talk about the ingredients in this very lengthy plan that would go into effect and would produce everything we need. I mean, it would ultimately give us recycling, and in the process it would do many other things. But I, frankly, don't think we can wait, and I don't think we can spend that much money, getting where we need to go, as soon as we need to.

Thank you, Mr. Chairman.

[The prepared statement of Senator Domenici follows:]

PREPARED STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM  
NEW MEXICO

Mr. Chairman, I appreciate you taking time to hold a hearing on a topic that I feel passionately about—addressing our spent nuclear fuel problem. To date, this is an issue this Congress has conveniently ignored.

Mr. Chairman, last year I chaired a hearing in the Energy and Water Subcommittee on Appropriations that was virtually identical to the hearing today. At that hearing we discussed the costs and benefits of GNEP, the opportunities to change the way we handle spent nuclear fuel and, of course, the nonproliferation responsibilities. We even had some of the very same witnesses.

That hearing, like today's, demonstrated that there was a broad consensus that this country should be pursuing research and development of advanced recycling technologies. To this end, the Department of Energy has developed, and Congress has supported, an ambitious program called GNEP. I am pleased to say that the only real debate now is on the timing of deployment of these technologies.

Over the past couple of months, two separate entities have filed combined license applications to build four new nuclear reactors—the first such license applications in almost 30 years. The nuclear renaissance is underway.

Ten years ago, many people—inside the industry and out—thought they'd never live to see this day. But ten years ago, I gave a speech at Harvard in which I made a commitment to do what was necessary to allow nuclear power to reach its full potential in this country. The fulfillment of that commitment involved years of regulatory oversight and legislative efforts that reached its peak in the provisions of the Energy Policy Act of 2005.

However, there is one issue that we are still lagging behind on, and that is what to do with our nuclear waste. Ten years ago, I declared, and I still believe, that we must close the fuel cycle, developing advanced fuel recycling technologies that will provide a long-term, secure, economic source of fuel, while simplifying the permanent disposal of waste residues and maximizing repository capacity.

We know this is possible. France, Japan and others have followed this path. We can make improvements on these programs; there are technologies that are more proliferation resistant that are waiting to be developed. However, time is not on our side. While the research portion of GNEP is important, we cannot let the pursuit of perfection stop us from pursuing what is good and achievable today.

The status quo is not an option. CBO recently testified that the government's liability for its failure to take spent fuel will grow to \$7 billion if Yucca Mountain opens in 2017, and \$11 billion if it opens in 2020. That translates into about \$1.3



billion per year. Now, remember that DOE has testified that the 2017–2020 opening date for Yucca Mountain is only achievable if a whole series of legislative changes are made. I have introduced a bill that addresses these issues. I would love to be wrong about this, but I just don't see that bill moving anytime soon.

Further, Congress put a statutory 70,000 metric ton limit on the amount of fuel that can be placed in the repository. This means that Yucca Mountain will be full before the day it opens—that's just counting the fuel from our existing fleet of reactors. Thus, current law says we must start looking at our second repository before we even open the first.

We must have a path forward—not fifty years from now, but NOW. We are left with only one choice—focus on an integrated spent fuel strategy that will address our liability question immediately, and implement a recycling strategy that will avoid the political and economic nightmare that would result from attempts to site a second repository, as the current law requires.

For over a decade, I have believed we should close the nuclear fuel cycle and begin to extract the vast energy potential that exists in spent fuel. Despite the skepticism here in this country and on this committee, the Global Nuclear Energy Partnership is being well received internationally. Sixteen countries have joined as our partners in addressing the global expansion of spent fuel.

Mr. Chairman, I'm sure I will find today's hearing very frustrating as we attempt to rationalize the various economic analyses to determine whether GNEP should be pursued while we ignore billions of dollars of direct costs to the American taxpayer that continue to result from our flawed Yucca Mountain strategy.

Having said that, I look forward to hearing from our witnesses.

The CHAIRMAN. All right, let me go ahead and introduce the witnesses. We have a full array of witnesses here, six very distinguished witnesses, and I want to hear from all of them.

I think our first witness will be the Administration witness, Dennis Spurgeon, who is the Assistant Secretary of the Office of Nuclear Energy in the Department of Energy.

Next is Peter Orszag, who is the Director of the Congressional Budget Office.

Next is Terry Wallace, who is at Los Alamos National Laboratory, next is Neil Todreas who is at MIT, a Professor at MIT.

Next, Matthew Bunn, who is a Ph.D. with Belfer Center for Science and International Affairs at Harvard.

Pattabi Seshadri who is with the Boston Consulting Group.

Thank you all very much, I gave you a little bit out of order there, I think Dr. Bunn, you're in the order of seating, I should have introduced you before Dr. Todreas.

But, anyway, let me ask you to just go across the table here, and give us the benefit of your views. If each of you could take 6 or 8 minutes and give us the main points that you think we need to understand. Then we will have some questions.

Secretary Spurgeon, go right ahead.

#### **STATEMENT OF DENNIS R. SPURGEON, ASSISTANT SECRETARY FOR NUCLEAR ENERGY, DEPARTMENT OF ENERGY**

Mr. SPURGEON. Thank you, sir. Chairman Bingaman, Ranking Member Domenici and members of the committee, it is a pleasure to be here today to discuss the Global Nuclear Energy Partnership or GNEP, as it relates to U.S. policy on nuclear fuel management. I might add that I look forward to engaging in a discussion to answer the questions and discuss the issues that were brought up by both the Chairman and the ranking member in their opening statements.

I would request, Mr. Chairman, that my written statement be inserted into the record, I also would like to insert 4 documents that

provide additional background and perspective. These documents include the GNEP Statement of Principles; an address before the International Atomic Energy Agency Scientific Forum, I delivered on September 18, that's entitled: Innovation, Research, and Development for the Next Quarter Century; a report by the GNEP Independent Review Group, made up of members with expertise relevant to GNEP; and finally, a letter from Secretary of Energy, Samuel Bodman to the President of the National Academy of Sciences in response to the National Research Council's review of DOE's nuclear energy research and development program.

The CHAIRMAN. We'll be glad to include the statement of each of you in the record in full, and we'll include those other documents, as well.

Mr. SPURGEON. Thank you, sir.

At the outset, let me stipulate that while some aspects of GNEP have evolved as we have engaged the international community, industry and other stakeholders—and I would add that it will continue to evolve—the GNEP vision remains unchanged. This vision is to promote a significant, wide scale use of nuclear energy in a safe and secure manner, and to take actions now that will allow that vision to be achieved while decreasing the risk of nuclear weapons proliferation and effectively addressing the challenge of nuclear waste disposal.

GNEP was created to realize these goals, and to ensure the United States is not only a participant, but that we regain our role as global leaders in nuclear energy.

In the short time I have to describe the complex and multi-faceted GNEP program, I think it is most important to understand the basic principles that guide the overall GNEP effort. The statement of principles is outlined on the board you see before you.

This Global Nuclear Energy Partnership is cooperation of those States that share the common vision of the necessity of the expansion of nuclear energy for peaceful purposes, in a safe and secure manner. This cooperation will be pursued with the following objectives: Expand nuclear power to help meet growing energy demand in a sustainable manner, and in a way that provides for safe operations of nuclear power plants, and management of wastes.

In cooperation with the IAEA, continue to develop enhanced safeguards to effectively and efficiently monitor nuclear materials and facilities, to ensure nuclear energy systems are used on for peaceful purposes.

Establish international supply frameworks to enhance reliable, cost-effective fuel services and supplies to the world market, providing options for generating nuclear energy and fostering development while reducing the risk of nuclear proliferation by creating a viable alternative to acquisition of sensitive fuel cycle technologies.

Develop, demonstrate, and in due course, deploy advanced reactors that consume transuranic elements from recycled, spent fuel.

Promote the development of advanced, more proliferation-resistant, nuclear power reactors, appropriate for the power grids of developing countries and regions.

Develop and demonstrate advanced technologies for recycling spent nuclear fuel, for deployment in facilities that do not separate pure plutonium, with a long-term goal of ceasing separation of plu-

onium, and eventually eliminating stocks of separated civilian plutonium. Such advanced fuel cycle technologies—when available—would help substantially reduce nuclear waste, simplify its disposition, and draw down inventories of civilian spent fuel in a safe, secure, and proliferation-resistant manner.

Finally, take advantage of the best available fuel cycle approaches for the efficient and responsible use of energy and natural resources.

Seventeen nations have now signed this Statement of Principles, and have become GNEP partners. Eighteen other nations, and three international organizations are participating as observers, and several of these nations are expected to join as partners.

The Advanced Fuel Cycle Initiative, technology research and development program, outlined in my written statement, is designed to provide the technology advancements needed in order to make the vision of GNEP and its objectives a reality.

The Secretary of Energy often remarks that there is no silver bullet to our energy challenges, or to climate change. However, he is quick to note nuclear power's potential of meeting the growing demand for energy, without producing greenhouse gases.

GNEP comes at a crucial time in the burgeoning expansion of nuclear power, and a crucial time for the Nation's energy security. It is the only comprehensive proposal to close the nuclear fuel cycle in the United States, and engage the international community to minimize proliferation risks, as well as provide—and benefit from—cooperation in policy formulation, technical support, and technology and infrastructure development.

Thank you, Mr. Chairman. I would be pleased to answer any questions you have.

[The prepared statement of Mr. Spurgeon follows:]

PREPARED STATEMENT OF DENNIS R. SPURGEON, ASSISTANT SECRETARY FOR  
NUCLEAR ENERGY, DEPARTMENT OF ENERGY

Chairman Bingaman, Ranking Member Domenici, and members of the committee, it is a pleasure to be here today to discuss the Global Nuclear Energy Partnership or GNEP as it relates to U.S. policy on nuclear fuel management.

It is my objective today to clearly define GNEP, discuss what has been accomplished, and what we plan to accomplish, and how we envision the program developing in the future. And in line with the hearing topic, GNEP is crucial to developing an effective and durable waste management strategy in the United States, as well as around the world. To that end, GNEP is completely compatible with our near-term effort to license and open the waste repository at Yucca Mountain, and as I will discuss, GNEP will complement and enhance its utility.

At the outset, let me stipulate that while some aspects of GNEP have evolved as we have engaged the international community, industry, and other stakeholders, the GNEP vision remains unchanged. This vision is to promote a significant, wide-scale use of nuclear energy in a safe and secure manner, and to take actions now that will allow that vision to be achieved while decreasing the risk of nuclear weapons proliferation and effectively addressing the challenge of nuclear waste disposal. GNEP was created to realize these goals and to ensure the United States is not only a participant, but that we regain our role as global leaders in nuclear energy.

*Why Nuclear?*

As this committee knows well, the Department of Energy (DOE) is tasked with promoting America's energy supply through reliable, clean, and affordable energy. It is clear today that with present energy demand projections, an expanded supply of electricity from a variety of resources must be expeditiously developed. The Energy Information Agency projects the demand for electricity in the United States will increase 50% by 2030, and global demand will nearly double over the same pe-

riod. It is this projected increase in electricity demand that provides the most compelling argument for the expansion of nuclear energy—both domestically and internationally.

Nuclear power is the only large scale, emissions-free source of baseload electricity currently available capable of meeting the growing demand.

Nuclear energy produces 20% of our nation's electricity, and almost 70% of our non-emitting source of domestic electricity. Last year, domestic nuclear power avoided an estimated 681 million metric tons of carbon emissions. That is the equivalent of eliminating carbon dioxide emissions from 96% of all passenger cars in the United States. Volumetrically, that amount of carbon dioxide would fill an area the size of Washington D.C. rising 1.2 miles.

Many countries around the world are concluding that increased nuclear generation is necessary to support economic growth and to avoid emitting additional greenhouse gases. The global expansion of nuclear power is a reality, with 32 reactors currently under construction and an estimated 222 in the planning phase.

Significant steps toward adding nuclear power generating capacity in the United States were taken last month with the first two complete submissions of combined Construction and Operating License applications to the Nuclear Regulatory Commission. Applications for 32 new nuclear plants are expected from 18 different utilities in the next 3 years. When completed, those plants will provide over 41,000 megawatts of electricity, enough power to supply almost 30 million homes with clean and reliable electricity.

#### *GNEP Vision*

Even as nuclear power helps the global community to keep pace with electricity demand, this increased use raises two important concerns: How will the world community deal with the possibility that the expansion may raise the risk of nuclear weapons proliferation? And, how will used fuel from nuclear power be best managed? The President addressed these concerns, and offered an approach to meet the projected growing demand for electricity and concerns over climate change when he announced the Global Nuclear Energy Partnership in February, 2006.

The National Security Strategy of the United States of America (March 16, 2006) establishes that the United States “will build the Global Nuclear Energy Partnership to work with other nations to develop and deploy advanced nuclear recycling and reactor technologies. This initiative will help provide reliable, emission-free energy with less of the waste burden of older technologies and without making available separated plutonium that could be used by rogue states or terrorists for nuclear weapons. These new technologies will make possible a dramatic expansion of safe, clean nuclear energy to help meet the growing global energy demand.”

GNEP can advance the nonproliferation and national security interests of the United States, particularly by reinforcing policies that aim to reduce the spread of enrichment and reprocessing technologies, and eventually eliminating excess civilian plutonium stocks that have accumulated. GNEP is working to foster collaboration between developed and developing nations to overcome shared barriers to developing and expanding nuclear power, which include high capital costs for new projects, a high degree of requisite technical and industrial expertise, advanced technology development, and efficient regulatory policy.

At the core of the GNEP vision is strengthening nuclear nonproliferation, and improving safety, security, and safeguards to enable the expansion of civilian nuclear power for peaceful purposes. GNEP would make one of its primary contributions to reducing proliferation risk by establishing a reliable and comprehensive fuel service framework. By providing assured supply of fresh fuel and assured disposition of used fuel, this framework would help nations gain the benefits of nuclear power without the need to build their own sensitive fuel cycle facilities. This would discourage the spread of enrichment and reprocessing capabilities, which could be misused to produce weapons.

Additionally, the GNEP vision addresses management of used nuclear reactor fuel, an issue that is most important for the long-term viability of nuclear power. In the United States and in many countries throughout the world, the build-up of used nuclear fuel could inhibit the long-term expansion of nuclear power and requires significant resources to maintain the necessary security and international safeguards. Domestically, the GNEP vision is a closed U.S. nuclear fuel cycle that would benefit repository capacity, produce more manageable waste form, conserve resources, reduce current and future stocks of fissile material, and foster the expansion of clean and reliable electricity generation.

### *What is GNEP?*

The Global Nuclear Energy Partnership has both broad international and significant domestic aspects. The global aspect of GNEP is manifested through voluntary international partnership initiated by the United States. The domestic aspect is aimed at effectively managing both the resources available in used nuclear fuel and the associated waste. The Office of Nuclear Energy funds fuel cycle research and technology development at national laboratories and universities through the Advanced Fuel Cycle Initiative (AFCI) and coordinates activities with the Office of Science, the National Nuclear Security Administration, the Office of Civilian Radioactive Waste Management, and the Office of Environmental Management.

### *International Partnership*

The international partnership is an unprecedented voluntary alliance of nations that share the common vision of the necessity of the expansion of nuclear energy for peaceful purposes worldwide in a safe and secure manner. It aims to accelerate development and deployment of advanced fuel cycle technologies to encourage clean development and prosperity worldwide, improve the environment, and reduce the risk of nuclear proliferation by taking advantage of the best available fuel cycle approaches.

GNEP seeks to reduce the risk of nuclear proliferation worldwide by promoting technologies that will reduce foreign stockpiles of separated plutonium generated from the civil nuclear industry. It aims to enhance the international nonproliferation regime by demonstrating safeguard systems that incorporate advanced materials accountability, control, and monitoring to reduce the threat of diversion or misuse. It also aims to develop advanced reactor designs that reduce proliferation risks, and promote infrastructure development to build the capacity of developing nations to utilize clean and reliable nuclear power, while achieving the highest nonproliferation standards.

Cooperation will be carried out under existing, and where appropriate, new bilateral and multilateral arrangements. The international partnership is the overarching organization consisting of like minded nations under which current and future arrangements are developed to further the vision of GNEP set forth in the Statement of Principles,\* which has been signed by 17 nations.

The Global Nuclear Energy Partnership Statement of Principles outline seven key goals that constitute GNEP's comprehensive vision, identifying areas of cooperation ranging from closing the fuel cycle through recycling technology, to development of reactors appropriate for power grids in developing countries and regions, to cooperating with the International Atomic Energy Agency (IAEA) to strengthen safeguards against nuclear proliferation. In the words of Director General of the IAEA, Dr. Mohamed ElBaradei, at the September Ministerial: "GNEP is . . . comprehensive because it deals with all aspects of the fuel cycle, both the front end and the back end. GNEP also aims to establish a global partnership . . . Nuclear energy is an international concern and we need to man it on an international basis."

In an effort to further develop policy, technology and regulatory foundations, multilateral and bilateral arrangements within the partnership are being utilized. This cooperation maximizes opportunities for international cooperation and also allows a secure avenue for engaging in sensitive fuel cycle cooperation.

In addition to new arrangements, existing multilateral arrangements ensure a means to further international cooperation to achieve GNEP's stated goals. The Generation IV International Forum (GIF), a thirteen-nation research and development consortium, is leading the way toward innovative nuclear energy systems of the future. GIF has identified six advanced nuclear energy systems, and the consortium is pursuing the research and development pathways for establishing technical and commercial viability, demonstration, and potential commercialization. Advanced technology systems being explored under GIF share parallel objectives with GNEP, and GIF's work has wide-ranging applicability for GNEP technology. GIF is an active member of GNEP, recently attending the GNEP Ministerial meeting as an observer.

DOE's International Nuclear Energy Research Initiative (I-NERI) also plays an important and complementary role as an existing multilateral agreement. I-NERI, with five international partners, collaborates on research and development for advanced fuel cycle technology, as well Generation IV and hydrogen technology.

Bilateral cooperation that benefits GNEP in its international technical development efforts includes arrangements between the United States and Russia, Japan, China, Australia, and Jordan. As an example, the U.S.-Russian Bilateral Action

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\*The additional materials referred to in Mr. Spurgeon's statement have been retained in committee files.

Plan outlines national strategies in nuclear power; identifies the common basis for U.S.-Russian cooperation in advanced recycling reactors, exportable small and medium reactors, nuclear fuel cycle technologies, and nonproliferation-all tenets of GNEP. Similarly, under the U.S.-Japan Bilateral Program Plan, we have formed working groups to conduct joint research and development, furthering the work being carried out in other bilateral agreements under the GNEP umbrella.

#### *Research and Technology Development-AFCI*

International cooperation leverages technology development activities of several countries to maximize benefits to all. In that context, significant domestic technology development and industrial investment will be needed to realize the GNEP vision.

The Department of Energy and specifically, the Office of Nuclear Energy's technology mission objective is to facilitate the research and development of advanced technologies and make them available to market.

DOE facilitates both of these objectives through its AFCI program. The driving intent of AFCI is to close the nuclear fuel cycle by fostering existing technologies as well as to develop advanced technologies that are cleaner, more efficient, less waste-intensive, and possibly even more proliferation-resistant than the once through system.

In order to discuss the underlying technology AFCI is developing, it is important to understand what we are working to accomplish. To do this we need to look at the back end of the fuel cycle as an integrated system. The fundamental goal of closing the fuel cycle is to separate used fuel into reusable materials and waste. Through this process, both components may be more efficiently managed. This allows not only the reuse of the fissionable materials that can provide significant amounts of energy, but also provides options for minimizing and efficiently managing the resulting waste.

In our current "once-thru" fuel cycle, the used nuclear fuel is planned for ultimate disposal in a permanent geological repository at Yucca Mountain, Nevada. Recycling used nuclear fuel rather than permanently disposing of it in a repository would result not only in utilizing more of the energy in nuclear fuel, but also reduce the amount of material that needs disposal in a repository, and the level of risk posed by that material.

By separating just the uranium and plutonium for reuse as fuel, the remaining material could reach roughly the same level of radiotoxicity as the originally mined uranium ore in approximately 10,000 years. When advanced recycling technologies are deployed, the separation out of most long-lived actinides and fission products will result in an even greater reduction of risk and accordingly greatly diminish the amount of material that needs disposal in a repository.

Present day separation technologies allow uranium to be separated sufficiently enough to be re-enriched for use as fresh fuel. Modified versions of those technologies allow a plutonium-uranium combination to be extracted and made into fuel, but this would not achieve the ultimate goal of GNEP. More advanced technologies under development through AFCI could be able to further partition used fuel by extracting those chemical elements heavier than uranium, the transuranics, for use as fuel to further shorten the time it takes for the waste to reach the radiotoxicity of natural uranium. Making transuranic elements into fuel for use in a fast reactor, also under development in AFCI, could allow additional reductions of the long-term radiotoxicity of the waste, perhaps reaching the radiotoxicity of natural uranium within only hundreds of years. In practical terms, consuming the transuranic elements has the potential to increase the capacity of a repository by reducing overall volume and heat loading by more than a factor of ten.

Making this advanced process practical would require making the separation process reliable, but also establishing the ability to fabricate a fuel type that can be used in a fast reactor. The current fleet of light water reactors cannot operate with fuel consisting of these isotopes. Fuel development in AFCI will determine the optimum transuranic fuels which in turn will determine the optimum fast reactor technology.

Separation and recycling technology's foremost contribution is the overall reduction of nuclear waste that requires permanent disposal, and allows for repository medium flexibility. Advanced recycling would reduce the volume, heat-loading, also known as thermal output, and radiotoxicity of nuclear waste, and could exponentially increase the capacity of the geological repository at Yucca Mountain. The successful implementation of recycling would not replace the need for Yucca Mountain. However, GNEP's proposed recycling activity could mitigate the burden on Yucca Mountain's physical limits, and the actual and projected volumes of used nuclear fuel from the current fleet of nuclear reactors and new reactors. In practical terms

the ability to transmute, destroy, or burn transuranics in a fast reactor is the principal longterm waste management benefit of GNEP.

GNEP's principles set the path to develop and demonstrate advanced technologies for recycling used nuclear fuel for deployment in facilities that do not separate pure plutonium and eventually eliminate stocks of separated civilian plutonium. Such advanced fuel cycle technologies, when available would help substantially reduce nuclear waste, simplify its disposition and draw down inventories of civilian used fuel in a safe, secure, and proliferation-resistant manner. They would also end the foreign accumulation of separated plutonium in the civil fuel cycle and draw down existing excess stocks worldwide.

#### *GNEP Activities*

GNEP is not a static vision, and its related policies and technologies are capable of evolving to meet the ultimate goals of the United States. Since the introduction of the Global Nuclear Energy Partnership last year, we have pursued an aggressive path of seeking input and collaboration in many venues.

#### INTERNATIONAL

The GNEP vision is set forth in the Statement of Principles. The landmark first Ministerial meeting on May 21, 2007, was hosted by U.S. Secretary of Energy Samuel Bodman. Ministers and atomic energy officials from China, France, Japan, Russia, and the United States gathered to engage in productive discussion and issued a Joint Statement of Support that clearly recognized the role of nuclear power and a common approach to nuclear power consistent with GNEP vision.

The second Ministerial meeting was held on September 16, in Vienna, Austria. The meeting was attended by a total of 35 nations and three inter-governmental organizations. Sixteen nations signed the Statement of Principles at the meeting and several others indicated interest in signing and becoming a partner upon formal review by their governments. The partners include the original five countries, China, France, Japan, Russia, and the United States, and eleven new countries; Australia, Bulgaria, Ghana, Hungary, Jordan, Kazakhstan, Lithuania, Poland, Romania, Slovenia, and Ukraine. The partnership continues to grow, as evidenced by Italy announced decision to become a partner just yesterday.

In addition to the signing of the Statement of Principles, the September ministerial meeting established the structure and governing procedures for GNEP which provides for an executive committee, a steering group, and expert working groups. Two working groups were approved, and two further working groups are under consideration-setting the partner nations on a path to immediately begin working to address the challenges to development of comprehensive global nuclear fuel services, as well as the necessary nuclear infrastructure needed to ensure nuclear power is developed in a safe, secure, and responsible manner and is used only for peaceful purposes.

Therefore, GNEP is a vehicle for both international cooperation and technology development, and has, is, and will be seeking input as a means of making the partnership a dynamic operational mechanism. Collecting technical, budgetary and environmental data and input enables GNEP to adjust, working to make it the most effective, economic and technically feasible.

#### INDUSTRY

DOE initiated significant industrial input for GNEP in May 2007 when a Funding Opportunity Announcement (FOA) was issued. The FOA sought applications from commercial entities to provide technology development roadmaps, business plans, and a communications strategy supporting the GNEP conceptual design studies for a nuclear fuel recycling center and advanced recycling reactor. The conceptual design studies will address the scope, cost, and schedule to build the initial facilities. The technology development roadmaps will describe the state of readiness for their proposed processes and design concept, and the longer-term technology development needs to achieve the ultimate GNEP vision. The business plans will address how the market may facilitate DOE plans to develop and facilitate commercialization of advanced fuel cycle technologies and facilities. The communications plans will provide DOE with information on the dissemination of scientific, technical, and practical information relating to nuclear energy and closing the nuclear fuel cycle. DOE anticipates receiving responses describing commercial technology that may be deployable in the near-term.

In September DOE awarded over \$16 million to four industry-led consortia to begin producing this information and data. We will receive the first data in January

of next year and will potentially authorize further work with some of the consortia after analyzing the submissions.

#### CONGRESS

When GNEP was introduced as part of the President's Advanced Energy Initiative in the Fiscal Year 2007 budget request, we requested \$250 million for AFCI. The House of Representatives approved only \$120 million in its appropriations legislation and the Senate, as you know, did not ultimately pass an Energy & Water Appropriations bill. In accordance with the Joint Resolution ultimately enacted, AFCI was provided with \$167.5 million, one-third below the requested amount. As part of this appropriations process, we received significant input via "report language" accompanying the respective bills.

In February, we submitted the Fiscal Year 2008 budget request, which includes \$395 million for AFCI. The House of Representatives passed an appropriations bill providing only \$120 million in funding. The Senate has not passed its version of that legislation yet, but the Appropriations Committee approved a bill which would provide \$242 million. Again, Congress provided, and DOE has considered, significant input as part of this process. Additionally, as part of the Fiscal Year 2006 appropriations process, Congress provided funding to provide grants to entities desiring to host recycling facilities to conduct siting studies of the proposed sites. Ultimately, Congress has not provided the level of funding support the Administration felt necessary and DOE has sought to adjust the program accordingly.

#### PUBLIC

Perhaps most importantly, we have sought public input, and will continue to do so in the future. As previously discussed, in August 2006, DOE issued a Funding Opportunity Announcement making funds available to conduct detailed studies of potential GNEP sites. We received responses from entities representing 11 communities in eight states interested in hosting advanced recycling facilities, and awarded over \$10 million to conduct the studies.

In January, DOE initiated an environmental review of the GNEP program as part of the process established in NEPA. Subsequently we hosted 13 meetings across the country to receive public comment relating to the scope of this GNEP Programmatic Environmental Impact Statement (PEIS). Ultimately we received over 14,000 comments, and we are in the process of preparing a draft PEIS informed by those comments. We expect to issue the draft in the near future and will again host public meetings and receive comments that will be reviewed and assist us in finalizing the PEIS and preparing in coordination, a Record of Decision next year.

#### *NAS Response*

Given the scope of this hearing, I think it is incumbent upon me to address the recent report issued by the National Research Council (Council), and specifically as it treats GNEP. The report's ultimate conclusion that has subsequently received significant media coverage is that, "... the GNEP program should not go forward and it should be replaced by a less aggressive research program." DOE takes issue with several of the premises on which the Council based its conclusion, but I think it's important to first note that inherent in the conclusion is the presumption that DOE should continue to pursue efforts to close the fuel cycle.

However, the Council's conclusion is based on the incorrect premise that DOE has already made selection of technologies and is aggressively moving to facilitate commercialization of those technologies. The Council mistakenly assumed that because the UREX+ separations technology was developed in our National Laboratories and has been designated the "baseline" technology for development and comparison purposes that DOE has in fact selected UREX+, excluding all other technologies. Not only is this not an accurate reflection of the AFCI program, but such a path is not consistent with our National Environmental Policy Act process which ensures such decisions are made in a deliberate and transparent manner, with ample opportunity for public comment.

While the Council supports the goal of closing the fuel cycle to the point of rejecting a minority opinion to the contrary, DOE strongly disagrees with the lack of urgency the committee shows for this important mission. With large expected increases in the demand for electricity as well as serious concerns about climate change, a substantial increase in nuclear capacity is required worldwide. This creates a serious urgency to definitively develop an answer to the "waste question" that is credible and durable, that provides the opportunity for alternative waste disposition paths while also minimizing the requirement for geologic repositories, and makes the most efficient use of nuclear resources.



*Economic Justification*

Some have questioned the economic justification for closing the fuel cycle and doing so in the near-term. However, most who raise these questions fail to acknowledge that any effort seeking to close the nuclear fuel cycle must be viewed through a macro lens to accurately assess the aggregate costs and benefits. An economic analysis is incomplete without assigning representative value to the important benefits from fuel cycle options.

Previous analyses, including some to be discussed here today, attempt to compare a closed fuel cycle to a direct disposal approach. This is an appropriate comparison of fuel cycle strategies, but in doing so the analysis must consider not only the dollars expended, but also address the goals of the used fuel management, including: minimization of repository requirements in both size and quantity, maximization of repository medium options, conservation of resources, and unquantifiable benefits of positive environmental impacts such as greenhouse gas avoidance, and health benefits stemming from noxious emissions avoidance. Perhaps most notably, most analyses take a narrow and outdated view of the security and nonproliferation benefits of closing the fuel cycle and ignore the significant benefits of offering reliable fuel services to discourage the spread of sensitive fuel cycle technologies.

Beyond the omission of macro analyses, the current studies are heavily dependent upon the principal assumption that direct disposal will be available at a modest cost as we look toward an expansion of nuclear power. This assumption has not proven accurate to date. Additionally, the federal government continues to incur financial liability for failure to remove used fuel from existing reactor sites. This liability could approach \$7 billion if Yucca Mountain is opened in 2017, and will grow by an approximate annual average of \$500 million for each additional year of delay.

The nation's commercial reactors will have generated enough used fuel for Yucca Mountain to meet its current statutory capacity by the end of this decade, well before the current fleet of reactors is retired and before considering the next generation of plants. Given the challenges we have experienced in opening a repository, the assumption of unfettered expansion of direct disposal is tenuous. The burden of identifying the locations for multiple repositories is a cost that is avoided for at least a century by closing the fuel cycle. Separating used fuel allows for waste forms that can enable alternative, and likely cheaper, disposal options that were not available with a direct disposal approach.

One key nonproliferation goal of GNEP is to enable the global expansion of nuclear power without the spread of sensitive fuel cycle technologies that can contribute to nuclear proliferation. Most analyses comparing direct disposal with recycling do not consider the value of the U.S. participating in a system that would relieve nations of the need to develop these sensitive technologies indigenously. It is difficult to see how the U.S. could take a central role in a fuel supply and take-back arrangement unless we deploy a sustainable waste management system. Additionally, the opportunity to eliminate the civilian foreign stocks of separated plutonium worldwide is enhanced by the availability of additional U.S. power plants licensed to consume plutonium bearing fuels.

The opportunity costs of a closed fuel cycle are hard to quantify, however, an analysis best serves the public by going beyond the strictly monetary or accounting costs of technology development to include all benefits of a closed fuel cycle.

The Secretary of Energy often remarks that there is no silver bullet to our energy challenges or to climate change. However, he is quick to note nuclear power's potential of meeting the growing demand for energy. GNEP comes at a crucial time in the burgeoning expansion of nuclear power, and a crucial time for our nation's energy security. It is the only comprehensive proposal to close the nuclear fuel cycle in the United States, and engage the international community to minimize proliferation risks as well as provide and benefit from cooperation in policy formation, technical support, and technology and infrastructure development.

This concludes my prepared statement. I would be pleased to answer any questions you may have.

The CHAIRMAN. Thank you very much.  
Dr. Orszag, thank you for being here.

**STATEMENT OF PETER R. ORSZAG, DIRECTOR,  
CONGRESSIONAL BUDGET OFFICE**

Mr. ORSZAG. Mr. Chairman, Senator Domenici, other members of the committee thank you for having me this morning.

CBO's testimony this morning evaluates the cost of direct disposal versus reprocessing. Our conclusion is that under a variety of plausible sets of assumption, reprocessing is more expensive than direct disposal, and therefore, in evaluating these two approaches, you may need to weigh the costs against other policy objectives, and let me try to describe that in a little bit more detail.

First, on the economics of reprocessing. There are potential economic benefits or cost reductions from, for example, reducing spending on newly mined uranium, and extending the life of uranium resources, and also potentially on reducing the size and need for the capacity of a long-term repository. But, let me just spend a moment on that topic, because I know it's particularly important to this committee.

The primary restraint on a long-term repository is not the volume, but rather the heat of the stored waste. From that perspective, there is a potential benefit in terms of the waste from the reprocessing itself, does have lower heat content than spent fuel. However, once you reuse the reprocessed fuel, run it back through a reactor, that spent reprocessed fuel is hotter—it has a higher heat content—than once-through spent fuel. So, unless you are going to store the spent reprocessed fuel in some other temporary storage facility for an extended period of time to allow it to cool, you vitiate any potential benefits in terms of reducing the need or the capacity limitations of a long-term repository.

Senator DOMENICI. Would you state that again?

Mr. ORSZAG. Sure. You could imagine, again, the key thing in terms of the capacity of a repository is the heat content of the waste, and there's basically an ordering. The hottest is spent, reprocessed fuel, that is, you used the fuel once, you run it through a reprocessing facility, you use it again, you wind up with some waste product from that. That's the hottest—that is the highest heat content.

Below that is once-through spent fuel, that is, you run it through a reactor once, and that's what we traditionally have now, and that's spent fuel, and then below that is, you run the fuel through a reactor, you have spent fuel, you reprocess it, and the reprocessing process itself creates some waste, that does have lower heat content than the once-through spent fuel.

But the key point is, if you're going to store the waste from the spent, reprocessed fuel in a long-term repository, which ultimately you will need to do, you can vitiate any potential benefits in terms of the capacity needs of that long-term repository, from the reprocessing process.

So, those are the potential benefits. On the other hand, you do need to build a facility to undertake the reprocessing, and as I've already noted, you still do have some need for long-term storage.

We reviewed a variety of analyses that have been undertaken in comparing these two approaches—including some that were conducted by people on this panel—and concluded that if you take the current 2,200 metric tons per year of waste that is produced by U.S. reactors, and look at the potential life of a reprocessing facility, and look at the relative costs of reprocessing versus direct disposal, in present value that is the amount today that is equivalent to those flows. Reprocessing would cost at least \$5 billion more

than direct disposal, which is roughly 25 percent more than the direct disposal option.

Now, there is a significant amount of uncertainty surrounding all of these numbers. For example, our analysis assumes that a reprocessing facility would operate at full capacity, basically continuously, and existing reprocessing facilities in other countries have not been able to do that. If the plant did not operate continuously, the cost of the reprocessing option would go up.

On the other hand, our analysis also assumes that the current elevated level of uranium spot prices will not be perpetuated over a very long period of time. If uranium prices remain very high for a very long period of time, that makes reprocessing more attractive, because one of the benefits of reprocessing is you reduce the need for newly mined uranium.

Our conclusion, we believe, is relatively robust across a variety of these assumptions, however, which is why I stated it the way I did. I would note that we did not take into account, where we did the analysis evaluating thermal reactors, and not advanced burner reactors, and overall analysis of GNEP, including the advanced burner part of it would require a whole variety of different analyses, and it would involve different cost considerations, also. So, our analysis is for thermal reactors, and existing reprocessing technologies.

Final point is, although reprocessing under a variety of plausible assumptions does cost more than direct disposal, there are other important policy objectives that may be worth taking into account in evaluating these two options, including extending uranium resources, including any potential effects on proliferation, and again, depending on exactly what is done with the spent, reprocessed fuel, including the capacity of a long-term repository.

Thank you very much.

[The prepared statement of Mr. Orszag follows:]

PREPARED STATEMENT OF PETER R. ORSZAG, DIRECTOR, CONGRESSIONAL  
BUDGET OFFICE

COSTS OF REPROCESSING VERSUS DIRECTLY DISPOSING OF SPENT NUCLEAR FUEL

Mr. Chairman, Senator Domenici, and Members of the Committee, thank you for the invitation to discuss the Congressional Budget Office's (CBO's) analysis of the costs of two alternatives for the use and disposal of nuclear fuel. For the past 50 years, the nuclear waste produced at reactors across the United States has largely been stored at the reactor sites. That practice, however, has been deemed untenable for the long run.

CBO's analysis compares the cost of two fuel-cycle alternatives for the current generation of thermal reactors. One alternative is direct disposal (as stipulated by current law), which involves using nuclear fuel once, cooling it at an interim storage site, and then disposing of it in a long-term repository. The second alternative is reprocessing, in which spent nuclear fuel is cooled and then reprocessed for one additional use in a reactor, and the wastes from reprocessing are stored in a long-term repository.

My testimony makes the following key points:

- The cost of directly disposing of spent nuclear fuel is less than the cost of reprocessing it. That basic result holds across a wide range of plausible assumptions, but the magnitude of the cost difference between the alternatives varies significantly among different analyses.
- Two studies illustrate the range of estimates of the cost difference between reprocessing and direct disposal. A study by the Boston Consulting Group estimates that reprocessing spent nuclear fuel would cost \$585 per kilogram-or

about 6 percent more than direct disposal. CBO's analysis of another study, by a group of researchers affiliated with Harvard University's Kennedy School of Government, suggests that reprocessing would cost about \$1,300 per kilogram or more than twice as much as direct disposal.

- From its analysis of those and other studies, CBO concludes that for the roughly 2,200 metric tons of spent fuel produced each year in the United States, the reprocessing alternative would be likely to cost at least \$5 billion more in present-value terms than the direct-disposal alternative over the life of a reprocessing plant. (Present-value figures convert a stream of future costs into an equivalent lump sum today.) The cost of reprocessing would be at least 25 percent greater than the cost of direct disposal.
- Major sources of uncertainty in such estimates include how much it would cost to build and operate a reprocessing facility, how long the facility would last, and the market value of reprocessed fuel.
- Policymakers evaluating the reprocessing and direct-disposal options may be concerned not only about cost but also about such potentially important issues as the impact of the alternatives on the threat of nuclear proliferation and the need for long-term storage space for spent fuel. Those issues are largely beyond the scope of CBO's analysis.

#### BACKGROUND ON NUCLEAR FUEL-CYCLE ALTERNATIVES

As of 2006, 104 nuclear reactors were operating in the United States, with a collective generating capacity of about 100 gigawatts of electricity. Those reactors account for nearly 20 percent of the electricity produced in this country.<sup>1</sup>

All of the commercial nuclear power plants in the United States generate electricity by relying on the uranium-235 isotope to sustain a nuclear reaction. Uranium-235 is relatively scarce and typically makes up less than 1 percent of mined uranium ore. The bulk of that ore consists of uranium-238, which cannot be used directly to sustain a nuclear fission chain reaction. For a sustained reaction to occur, the uranium must be enriched—that is, the proportion of uranium-235 must be increased, generally to between 3 percent and 5 percent in the case of fuel for civilian reactors.

After approximately four years in a reactor, too little uranium-235 remains in the fuel to generate electricity. The spent fuel can be handled in one of two ways: Under direct disposal, it is placed in interim storage for cooling, with the goal of eventually storing it in a stable geologic formation over the long term. Under reprocessing—which is done in a few countries but not the United States—a reprocessing facility recovers the useful components of the spent fuel (uranium and certain forms of plutonium) and returns them to the fuel cycle, where they are combined with newly mined uranium to produce more reactor fuel (see Figure 1).<sup>\*</sup> Any waste remaining from the spent nuclear fuel after the uranium and plutonium are removed is intended to be stored in a long-term repository. Thus, under either option, some form of long-term storage facility is necessary.

No long-term repository for storing commercial nuclear waste is currently operating anywhere in the world. The Department of Energy (DOE) is planning to build and operate such a repository at Yucca Mountain in Nevada. That facility, originally scheduled to open in 1998, is now intended to start operating in 2017, although a later opening date—2020 or 2021—is more likely.<sup>2</sup> That date would be nearly 40 years after lawmakers directed DOE to begin studying potential sites for a deep underground repository for spent nuclear fuel.<sup>3</sup>

With such delays, the accumulated stock of nuclear waste is expected to exceed Yucca Mountain's mandated capacity before the facility begins accepting waste for storage. One approach to that problem is to expand the repository's capacity, either physically or by lifting the mandated limit on how much waste Yucca Mountain can accept (an option that many observers believe could be undertaken without compromising safety). Another approach is to reprocess spent nuclear fuel for reuse in reac-

<sup>1</sup>Department of Energy, Energy Information Administration, Annual Energy Review 2006 (June 2007), Table 8.2a, available at [www.eia.doe.gov/emeu/aer/pdf/pages/sec8\\_8.pdf](http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8_8.pdf).

<sup>\*</sup>Figures 1–3 have been retained in committee files.

<sup>2</sup>Statement of Edward F. Sproat, Director, Office of Civilian Radioactive Waste Management, at the 178th meeting of the Nuclear Regulatory Commission's Advisory Committee on Nuclear Waste, April 10, 2007, available at [www.nrc.gov/reading-rm/doc-collections/acnw/tr/2007/nw041007.pdf](http://www.nrc.gov/reading-rm/doc-collections/acnw/tr/2007/nw041007.pdf).

<sup>3</sup>As originally enacted, the Nuclear Waste Policy Act of 1982 called for studies of three potential sites for long-term geologic repositories. Sections 5011 and 5012 of the Nuclear Waste Policy Amendments Act of 1987 effectively cancelled any investigation into sites other than the one at Yucca Mountain.

tors. That option could increase the effective capacity of the repository by allowing more nuclear waste to be stored in a given amount of space.

The main factor that determines the overall storage capacity of a long-term repository is the heat content of nuclear waste, not its volume. The waste that results from reprocessing spent fuel from thermal reactors has a lower heat content (after a period of cooling) than the spent fuel itself does. Thus, it can be stored more densely.<sup>4</sup> The extent of that densification directly affects the relative costs of direct disposal and reprocessing. However, unlike waste from the reprocessing process, spent fuel that has been reprocessed and used again has a higher heat content than spent fuel that has been used only once. Storing that previously recycled spent fuel in the long-term repository immediately would eliminate all of the densification benefits of reprocessing, onsequently, for reprocessing to reduce the need for-and cost requirements of-long-term storage, previously recycled spent fuel would have to be allowed to accumulate at some location outside the repository.

Besides potentially lowering long-term disposal costs, reprocessing spent nuclear fuel has the advantage of reducing expenditures for freshly mined and enriched uranium. In effect, recovering unused uranium from spent fuel extends the life of unmined uranium resources. Furthermore, recovered plutonium is not subject to many of the fuel-preparation costs (such as for conversion and enrichment) that are necessary with uranium (see Figure 1). That potential for front-end savings was especially appealing when the U.S. commercial nuclear program began in the 1950s. It became less pronounced by the 1960s, as uranium prices declined and uranium preparation techniques matured. Spot prices for uranium have recently reached historical highs (adjusted for inflation), but high prices would have to persist for decades to increase the economic viability of reprocessing.

Reprocessing and direct disposal differ not only in potential costs but also in possible risks for the proliferation of nuclear weapons. Spent nuclear fuel itself poses little risk of proliferation because the plutonium it contains is mixed with highly radioactive elements and can be recovered only in dedicated reprocessing facilities.<sup>5</sup> But the most widely used method of reprocessing-called plutonium and uranium recovery by extraction, or PUREX-yields pure plutonium, which has relatively low radioactivity and can be handled directly. Thus, the PUREX method recovers plutonium in a form that poses risks for theft and proliferation. Other reprocessing methods being considered by policymakers try to reduce those risks by not separating pure plutonium from spent fuel.

#### REPROCESSING FACILITIES

The United States has limited experience with commercial reprocessing. Three reprocessing plants were built for commercial use, but only one-a plant in West Valley, New York, that opened in 1966-achieved any level of operation. The need for costly upgrades caused it to close in 1976, having handled only spent fuel from national defense operations.<sup>6</sup>

Today, five nations-France, the United Kingdom, Japan, Russia, and India-have or are developing reprocessing facilities. The world's largest reprocessing plant is located in La Hague, France, and has a gross capacity of 1,700 metric tons per year. The United Kingdom has two reprocessing centers at its Sellafield Nuclear Site: a 900-metric-ton thermal oxide reprocessing plant (THORP) and a facility that specializes in reprocessing waste for two specific British nuclear facilities (Oldbury and Wylfa, both of which are expected to cease operations by 2010). Another reprocessing facility has been under construction in Rokkasho, Japan, since the late 1980s. The start of commercial operations there has been delayed several times but is now expected to occur later this year.

#### THERMAL REACTORS VERSUS FAST-NEUTRON REACTORS

CBO's analysis compares the cost of reprocessing nuclear fuel from thermal reactors-the type of commercial reactor used now in the United States-with the cost of using uranium fuel a single time and then putting all of it in a geologic repository. However, some policy initiatives, such as the Global Nuclear Energy Partnership, have focused on another type of reactor: an advanced burner reactor, which is a type

<sup>4</sup>The "densification factor" describes that relationship; for example, a densification factor of 2 indicates that twice as much waste from reprocessing can be stored at the same total cost (in other words, that the unit cost of storage is half as much).

<sup>5</sup>Steve Fetter and Frank N. von Hippel, "Is U.S. Reprocessing Worth the Risk?" *Arms Control Today* (September 2005), available at [www.armscontrol.org/act/2005\\_09/Fetter-VonHippel.asp](http://www.armscontrol.org/act/2005_09/Fetter-VonHippel.asp).

<sup>6</sup>Anthony Andrews, *Nuclear Fuel Reprocessing: U.S. Policy Development*, Report for Congress RS22542 (Congressional Research Service, November 29, 2006).

of fast-neutron reactor. Whereas thermal reactors rely on less energetic, or modulated, neutrons to sustain a nuclear chain reaction, fast-neutron reactors rely on unmodulated (and hence more energetic) neutrons for a reaction. Fast-neutron reactors use plutonium as a fuel source rather than uranium because plutonium maintains a reaction with unmodulated neutrons more readily than commercialgrade enriched uranium does.

Fast-neutron reactors offer several advantages. They can convert plentiful uranium-238 (which is not usable for nuclear chain reactions) into plutonium in such a way as to produce (or breed) more plutonium than the reactor itself uses. In that way, a fast-neutron breeder reactor can extend uranium resources by accessing 60 to 100 times more of the energy content of uranium than thermal reactors can.<sup>7</sup> Fast-neutron reactors also generate less spent fuel than thermal reactors do. Besides uranium and plutonium, spent nuclear fuel includes two other types of waste: fission products and minor actinides. Minor actinides decay less rapidly than fission products do. Because the capacity of a geologic repository depends to a significant degree on the long-term radioactivity of waste, it is greatly influenced by the amount of minor actinides present in spent fuel. Advanced burner reactors can potentially burn all of the actinides in nuclear fuel, so waste from those reactors requires less geologic storage space than does either spent nuclear fuel from thermal reactors or the waste from reprocessing thermal reactors' spent fuel.

Whereas reprocessing spent fuel is merely an option with thermal reactors (to extend uranium resources or to potentially expand long-term storage capacity), it is an integral part of the fuel cycle for advanced burner reactors. The fuel needed to power advanced burner reactors can be collected by reprocessing spent fuel from thermal reactors or from burner reactors. Furthermore, if burner reactors are used to reduce thermal-reactor waste, spent nuclear fuel must be reprocessed.

This testimony does not consider reprocessing in the context of fast-neutron reactors, for three reasons. First, no commercial fast-neutron reactors exist in the United States and none are planned. Second, the 60-year-old PUREX process is essentially the only reprocessing method now used for thermal reactors, and given its long history, the cost of PUREX is better known than the costs of more-recent reprocessing technologies that are being considered for fast-neutron reactors. Third, reprocessing fuel for advanced burner reactors would probably require reprocessing nuclear waste from thermal reactors as a first step to create the fuel for the burner reactors and to manage any existing thermal-reactor waste. Thus, reprocessing thermal-reactor waste can be thought of as a transitional element to a burner-reactor program.

#### COST COMPARISONS FOR DIRECT DISPOSAL AND REPROCESSING

Reprocessing nuclear fuel could have several economic advantages over direct disposal. It could reduce spending on newly produced uranium fuel and extend the useful life of uranium resources. In addition, it could save money on long-term storage by reducing the size of the repository necessary to handle spent nuclear fuel or by delaying the need to expand such a facility in the future.

With current reactor technology, reprocessing would also have economic disadvantages. First, it would require building dedicated facilities to recover the useful components of spent nuclear fuel and then to combine them into a form usable in a nuclear reactor. Second, previously recycled spent fuel would also need some form of long-term storage.

To quantify the relative costs of reprocessing and direct disposal, CBO's analysis focuses on the costs of handling nuclear fuel after it is discharged from a reactor. In the case of reprocessing, those costs include the costs of reprocessing services (both recovering uranium and plutonium and fabricating them into usable nuclear fuel), transportation, and long-term disposal of wastes, partially offset by "fuel credits," which various models use to reflect the value of the reprocessed fuel (in the form of savings on the costs of newly purchased fuel). In the case of direct disposal, the costs in this analysis include costs for interim storage to cool the spent fuel, transportation, and long-term disposal.

CBO reviewed a number of studies that shed light on the costs of nuclear fuelcycle alternatives, including reports by the National Research Council, the Massachusetts Institute of Technology, the Idaho National Laboratory, and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD).<sup>8</sup>

<sup>7</sup>Uranium Information Centre, *Fast Neutron Reactors*, Briefing Paper No. 98 (Melbourne, Australia: Australia Uranium Association, June 2006), available at [www.uic.com.au/nip98.htm](http://www.uic.com.au/nip98.htm).

<sup>8</sup>National Research Council, *Nuclear Wastes: Technologies for Separations and Transmutations* (Washington, D.C.: National Academy Press, 1996); Massachusetts Institute of Technology, *The Future of Nuclear Power* (Cambridge, Mass.: MIT, 2003), available at <http://web.mit.edu/>

However, CBO's analysis focused on two studies in particular: a 2006 report by the Boston Consulting Group (BCG) and a 2003 report by researchers at Harvard University's Kennedy School of Government.<sup>9</sup> Those two studies are the only recent analyses available that investigate the costs of all facets of both reprocessing and direct disposal (including transportation, interim storage, and credits for recycled fuel). Other studies consider only the costs of reprocessing or do not examine the various components of total costs. In addition, the two studies' estimates of the cost of reprocessing services—one of the largest cost elements—bound the range of estimates provided in, or implied by, the other studies. The Kennedy study's estimate of the cost of reprocessing services is about twice the size of the BCG study's estimate. Other studies that CBO examined had cost estimates for reprocessing services that fell within the range defined by those two reports.

#### EVALUATING THE BOSTON CONSULTING GROUP AND KENNEDY STUDIES ON A COMMON GROUND

The BCG study concludes that reprocessing spent fuel costs about \$30 more per kilogram than direct disposal (which the study estimates at \$555 per kilogram). To directly compare that estimate with the results of the Kennedy study, CBO modified the Kennedy study to reflect a similar initial framework as in the BCG study. In that framework, the Kennedy study implies that reprocessing costs about \$700 more per kilogram than direct disposal. Given the volume of waste expected to be generated over the lives of the plants evaluated, those estimates suggest that the present-value cost of reprocessing exceeds that of direct disposal by about \$2 billion for the BCG study and by about \$26 billion for the Kennedy study, as modified by CBO. (Present-value calculations use a discounted cost framework that describes the amount of funds that would be necessary in 2007 to pay all of the costs of a waste-management option over the assumed lifetime of a reprocessing plant.)

Several differing assumptions account for much of the gap between those two present-value estimates. Such assumptions include the interest rate used to estimate the present value of future costs (the discount rate), the relationship between a reprocessing plant's yearly operating costs and total capacity costs, the time horizon over which the plant operates, the cost of a long-term repository, and the degree to which waste from reprocessing can be stored more densely than spent nuclear fuel in the repository. Changes to any of those assumptions will affect the relative costs of the two waste-handling alternatives. To control for those differences, CBO's analysis imposed a common set of cost assumptions on the estimates from the BCG study and from the modified Kennedy study. In particular, CBO assumed the following:

- A discount rate of 3.5 percent, which lies between the rates used in the two studies.
- Plant operating costs that equal 6 percent of the plant's capital costs, a rule of thumb adopted in an analysis by OECD's Nuclear Energy Agency.<sup>10</sup> That figure lies between the 4.6 percent ratio implied by the BCG study and the 7.5 percent ratio implied by the Kennedy study.
- A lifetime of 40 years for a reprocessing plant, the midpoint between the 50-year figure used in the BCG study and the 30-year lifetime assumed in the Kennedy study.
- Repository costs of \$1,036 per kilogram of heavy metal stored in the repository, an estimate that CBO developed using cost data from DOE. That cost exceeds both the \$736 per kilogram figure in the BCG study and the \$868 per kilogram estimate in the Kennedy study.

nuclearpower; D.E. Shropshire, *Advanced Fuel Cycle Cost Basis* (Idaho Falls: Idaho National Laboratory, April 2007), available at [www.inl.gov/technicalpublications/Documents/3667084.pdf](http://www.inl.gov/technicalpublications/Documents/3667084.pdf); and Nuclear Energy Agency, *The Economics of the Nuclear Fuel Cycle* (Paris: Organization for Economic Co-operation and Development, 1994), available at [www.nea.fr/html/ndd/reports/efc](http://www.nea.fr/html/ndd/reports/efc).

<sup>9</sup>Boston Consulting Group, *Economic Assessment of Used Nuclear Fuel Management in the United States* (study prepared for AREVA Inc., July 2006); and Matthew Bunn and others, *The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel* (Cambridge, Mass.: Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, December 2003).

<sup>10</sup>Nuclear Energy Agency, *Accelerator-Driven Systems and Fast Reactors in Advanced Nuclear Fuel Cycles: A Comparative Study* (Paris: Organization for Economic Co-operation and Development, 2002), p. 211, available at [www.nea.fr/html/ndd/reports/2002/nea3109.html](http://www.nea.fr/html/ndd/reports/2002/nea3109.html).

- A densification factor of 2.5 applied to repository capacity, based on the study by the Idaho National Laboratory.<sup>11</sup> That figure is between the factor of 4 used in the BCG study and the factor of 2 implied by the Kennedy study.

As those common assumptions are applied successively, the two present-value estimates of the difference between reprocessing and direct-disposal costs narrow from a range of \$2 billion to \$26 billion to a range of \$5 billion to \$11 billion (see Figure 2).

Most of that remaining gap is attributable to the two studies' different assumptions about the costs of building and operating a reprocessing plant. The BCG study estimates construction costs at about \$17 billion for a plant with a capacity of 2,500 metric tons per year. A meaningful comparable estimate cannot be derived from the Kennedy study because that analysis does not explicitly differentiate between capital and operating costs. The likelihood that a newly built U.S. plant would match either study's cost assumptions is difficult to judge; the historical record provides scant evidence about the overall cost of a reprocessing facility and its component parts. Not only are there few large-scale commercial reprocessing plants, but only limited information is available about their construction and operating costs.

Neither the 900-metric-ton THORP facility in the United Kingdom nor the 1,700-metric-ton La Hague facility in France has enough capacity to handle the 2,200 metric tons of nuclear waste generated in the United States each year—the amount considered in this analysis. Thus, a facility larger than any past or current example would be necessary if a single reprocessing plant was to handle the United States' entire annual output of spent nuclear fuel.

A larger facility would be more costly than existing plants, although to what degree is unknown. The limited information available suggests that the THORP plant cost around \$6.3 billion to build (in 2007 dollars). The BCG study indicates that the construction cost of the La Hague facility was around \$18 billion (unlike the THORP estimate, however, that total includes a fabrication facility for recycled fuel, which increases the overall cost). The nearly complete 800-metric-ton Rokkasho facility will reportedly cost about \$21 billion, but part of that cost is attributable to specifics of the plant's location that would not necessarily apply to a U.S. facility. Given the lack of numerous commercial reprocessing facilities to use as examples, it is difficult to know how much geographic location, economies of scale, and regulatory environment affect the cost of a reprocessing plant.

All of the costs for reprocessing services included in this analysis assume that the plant would operate near capacity for its entire life. History, however, suggests that such an assumption might be optimistic and therefore that the unit cost of reprocessing could be higher than described here. Neither THORP nor La Hague has operated close to full capacity for a substantial period. THORP has been closed for more than two years after experiencing a radioactive leak. Before that, the plant operated at about 60 percent of capacity over its first 11 years. Although La Hague has not had the technical problems of the THORP facility, it too is operating well below full capacity: at approximately 65 percent, according to recent estimates. Operating at less than full capacity limits the amount of spent fuel that can be handled for a given cost.

Another factor that could increase the estimated cost of reprocessing relative to direct disposal is the discount rate used in present-value calculations. The rate assumed in this analysis is similar to those used in the BCG and Kennedy studies and slightly above a risk-free government rate—but it is well below the rate that might be applied for this type of project. A higher discount rate would result in a larger cost difference between reprocessing and direct disposal.

The relative cost of reprocessing is also affected by the market value of recycled fuel. As noted above, the fuel credits used in this analysis reflect front-end savings from using recycled fuel rather than newly mined uranium. If the costs of uranium mining and fuel preparation increased, and if recycled fuel proved to be a good substitute for newly mined uranium in nuclear reactors, higher fuel credits could offset the cost of reprocessing to a greater extent. Although uranium prices are currently high by historical standards, it is not certain whether high prices will continue in the future or whether current prices will encourage additional uranium development that could lower prices. Furthermore, modifying a nuclear reactor to use recycled fuel entails some costs, which would offset a portion of the potential fuel credits from reprocessing.

<sup>11</sup> Shropshire, *Advanced Fuel Cycle Cost Basis*, p. L-12.



## SENSITIVITY TO VARYING ASSUMPTIONS

Although the size of the cost difference between reprocessing and direct disposal depends on inputs to specific models, the conclusion that reprocessing is more expensive than direct disposal generally applies under various assumptions. CBO tested the sensitivity of the results to changes in some of the key parameters of this analysis.

- An increase of 1 percentage point in the discount rate increases the difference in present-value costs between reprocessing and direct disposal by between \$3 billion and \$4 billion.
- A reduction in the assumed operating costs of a reprocessing plant narrows the cost gap between reprocessing and direct disposal. For example, decreasing the ratio of a plant's operating costs to its capital costs by 1 percentage point reduces the present-value cost differential by between \$2 billion and \$3 billion. However, operating costs would have to be at least 50 percent lower for reprocessing to cost the same as or less than direct disposal.
- A change in the assumed operating lifetime of a reprocessing facility has no material impact on the cost differential for the two waste-handling alternatives.
- A rise in the cost of the long-term storage repository reduces the difference between the costs of reprocessing and direct disposal. That cost would have to increase to a very great extent, however, for direct disposal to cost as much as reprocessing. Even then, if the factors responsible for the increase (such as general growth in materials and construction costs) also applied to the cost of a reprocessing plant, reprocessing would continue to have a cost disadvantage.
- An increase in the extent to which waste from reprocessing can be stored more densely than unprocessed spent fuel (the densification factor) lowers the cost of reprocessing relative to direct disposal. However, reprocessing remains at a cost disadvantage under plausible values for densification.

In conclusion, the cost of reprocessing may be comparable to that of direct disposal under limited circumstances, but under a wide variety of assumptions, reprocessing is more expensive (given current reactor technology).

Policymakers weighing the merits of reprocessing and direct disposal may have other concerns besides cost—such as extending U.S. uranium resources, reducing the threat of nuclear proliferation by adopting advanced burner technologies, or lessening the demand for long-term storage space. Judging whether those goals justify the added costs of reprocessing is ultimately a decision for policymakers.

The CHAIRMAN. Thank you very much.  
Dr. Wallace, go right ahead.

**STATEMENT OF TERRY WALLACE, PRINCIPAL ASSOCIATE DIRECTOR, SCIENCE, TECHNOLOGY AND ENGINEERING, LOS ALAMOS NATIONAL LABORATORY, LOS ALAMOS, NM**

Mr. WALLACE. Good morning, Chairman Bingaman and Ranking Member Domenici, and the distinguished members of the committee. It is an honor to appear before you today to discuss the Global Nuclear Energy Partnership, or GNEP. I'm going to focus my remarks on the R&D challenges related to nuclear energy, and the capabilities of the Department of Energy's National Laboratories to address these challenges.

I am Terry Wallace, I am the principle Director for Science, Technology and Engineering at Los Alamos National Laboratory, and Los Alamos' mission is to develop and apply science and technology to ensure the safety, the reliability of the U.S. nuclear deterrent, to reduce the global threats, and to solve other emerging national security challenges. There certainly is no emerging challenge which is greater than that of energy.

Energy is a cornerstone of our Nation's prosperity, and the global demand is extraordinary. If the rest of the world's population enjoyed the U.S. standard of living today, it would require an immediate sixfold increase in energy production. This tremendous de-

mand for energy will have many unintended consequences, including an unfathomable increase in greenhouse gases. Nuclear energy is, and must be, an important component of a global energy supply.

It can be, provide reliable clean energy without generating additional CO<sub>2</sub>. However, a global renaissance in nuclear energy also generates concerns, as we've heard, about proliferation and waste.

DOE introduced GNEP as an international and holistic approach to managing the demand for nuclear power. The recent GNEP review by the National Academies, endorse closing the fuel cycle, and a more cautious approach to major facility implementation.

The Nation has the intellectual resources at its National Laboratories and universities to solve the technological challenges of the fuel cycle. However, there are significant research and development required to achieve an integrated fuel cycle. In particular, research is required in the following five areas.

First, in fuels development. The advanced nuclear fuels that were discussed by the previous two speakers in closed fuel cycle will contain transuranic elements, and many of these have not been used in reactors in the past. It will require the development of new fuel fabrication techniques. For much of GNEP's R&D experimental needs, the National Laboratories have specialized facilities to address this today.

One exception is the source of fast neutrons to test and certify new fuels. At the direction of Congress and DOE, for example, Los Alamos is working to build a materials test station, an enhancement of the Los Alamos Neutron Science Center, or LANSCE, which will be able to test these new fuels in a very cost-effective fashion.

The second area of research is separations. The main GNEP objective for separation of spent nuclear fuel is to reduce the proliferation risk associated with next generation processing plants, but also to reduce the volume of waste stored in geologic repositories.

Now there are several options, but one option's been investigated for separation is UREX-plus, which was developed at the AFCE, as the Assistant Secretary mentioned before.

The third area that we need research in is waste. A closed fuel cycle will result in separated waste streams. Particularly, separating the actinides and short-lived isotopes. These short-lived isotopes can be much more easily stored in, for example, a solid glass or vitrification, metal or ceramics, and these can be disposed of in a different type of geologic environment, or stored for a time sufficient to allow the radiotoxicity to be reduced.

The fourth area that research is required in is in safeguards. Research on material control and safeguard technologies to assure non-proliferation, can enable the safe and secure expansion of global energy in the U.S. and beyond. Research on an enhanced system will require building on safeguard technologies, which have been quite successful in the past. Many of these were created at Los Alamos, and they enable a real-time monitoring of facility operations, and accounting for all nuclear materials.

The fifth area of research is modeling and simulation. The advanced modeling and simulation tools, which have been developed for nuclear weapons work in stockpile stewardship by NNSA's advanced simulation and computing program, are now being applied

in GNEP. Systems analysis studies help define and quantify the benefits and disadvantages of various deployment options for expanded nuclear energy systems. Everything from uranium mining to reactive instruction, to the placement of waste in repositories.

In conclusion, the GNEP technology development program lays out a reasonable approach for closing the fuel cycle. We believe that with adequate R&D and critical investments in laboratory infrastructure, the basic processes and systems can be demonstrated at a reasonable scale and with a timetable that's consistent with the GNEP plan.

There are no technological showstoppers to closing the fuel cycle, and providing a global approach to a major expansion in nuclear energy.

I also thank you, and look forward to your questions.

[The prepared statement of Mr. Wallace follows:]

PREPARED STATEMENT OF TERRY WALLACE, PRINCIPAL ASSOCIATE DIRECTOR,  
SCIENCE, TECHNOLOGY AND ENGINEERING, LOS ALAMOS, NM

#### INTRODUCTION

Good morning Chairman Bingaman, Ranking Member Domenici, and distinguished members of the Committee. It is an honor to appear before you today to discuss the Global Nuclear Energy Partnership, or GNEP. I will focus my remarks on the R&D challenges related to nuclear energy, and the capabilities that the Department of Energy's national laboratories provide to address these challenges.

I am Terry Wallace, the Principal Associate Director for Science, Technology and Engineering at Los Alamos National Laboratory. Los Alamos' mission is to develop and apply science and technology to ensure the safety, security and reliability of the U.S. nuclear deterrent; reduce global threats; and solve other emerging national security challenges. No emerging challenge is greater than that of energy.

Energy is the cornerstone of our nation's prosperity and the global demand is extraordinary. If the rest of the world's population enjoyed the U.S. standard of living today, it would require an immediate six-fold increase in energy production. This tremendous demand for energy will have many consequences, including unfathomable increases in greenhouse gases. Nuclear energy is, and must be, an important component of the global energy supply. It can provide reliable, clean energy without generating additional CO<sub>2</sub>. However, a global renaissance in nuclear energy also generates concerns about proliferation and waste. GNEP provides a global vision that addresses these concerns. A key component of the GNEP plan is to offer international partners a secure fuel cycle, leasing fresh fuel and taking back of spent fuel.

#### GNEP RESEARCH AND DEVELOPMENT

DOE introduced GNEP as an international and holistic approach to managing the demand for nuclear power. Within the GNEP plan there are two research and development objectives: commercial deployment of existing technologies in the near-term, and a robust long-term research and development program to facilitate a closed fuel cycle. The recent review of GNEP by the National Academies endorsed closed fuel cycle technology and a more cautious approach to major facility implementation. The nation has the intellectual resource in its national laboratories and universities to solve the technological challenges of a new closed fuel cycle.

However, there is significant research and development required to achieve an integrated fuel cycle. In particular, research is required in the following five areas:

- 1.) *Fuels Development*: The advanced nuclear fuels in a closed fuel cycle approach will contain transuranic elements which will be transmuted (burned) in an advanced burner reactor (ABR). This will require development of new fuel fabrication techniques. The new fuels will have combinations of elements which have never been assembled in fuels before, and the performance of the ensemble is a rich topic for research. For much of GNEP's R&D experimentation needs, the national laboratories already have the required specialized facilities. One exception is a source of fast neutrons to test and certify new fuels. At the direction of Congress and the DOE, Los Alamos is working to build the Materials

Test Station, an enhancement at the Los Alamos Neutron Science Center (LANSCE), which will enable testing of new fuels in a very cost effective fashion.

2.) *Separations*: The main GNEP objectives for separations of spent reactor fuel are to reduce both the proliferation risk associated with next-generation processing plants, and the volume of waste to be stored in geological repositories. The UREX+ technology, developed within DOE's Advanced Fuel Cycle Initiative (AFCI), is one option being investigated to provide these benefits. These processes are being demonstrated with Light Water Reactor (LWR) spent fuel at small scale (e.g., the level of kilograms per test run). Substantial improvements are possible with further development work including the baseline extraction systems and product and waste form preparation. The next step is for the processes to be run at much larger scales and for extended periods to provide industry with the information required to design commercial-scale facilities. Separation methods beyond the aqueous UREX+ extraction system are also under development in the AFCI program, for example, electrochemical processes in molten salts for recycle of fast reactor spent fuels.

3.) *Waste*: One of the primary goals of the GNEP effort is to reduce the quantity and radiotoxicity of waste produced during nuclear power generation and to simplify the disposition of those wastes. It is important to note that this longer-term GNEP effort is complementary to the current initiative to license the Yucca Mountain repository. Los Alamos scientists are also actively participating in the DOE's effort to prepare the license application for Yucca Mountain for consideration by the Nuclear Regulatory Commission. Whereas Yucca Mountain is a permanent solution for the commercial spent nuclear fuel currently awaiting disposal, as well as defense high-level waste, the GNEP research addresses the important issue of how to further optimize the long-term management of nuclear waste in a way that enables the global expansion of nuclear power in a safe and secure manner throughout the 21st century.

The radiotoxicity and heat-generating characteristics of nuclear waste pose significant technical challenges. In contrast to the "once-through" open fuel cycle, in which spent nuclear fuel rods are sent to a geologic repository, the separations and reprocessing steps of the closed fuel cycle being pursued in the GNEP program would lead to separated waste streams containing individual or groups of radionuclides. This approach, though more complex from a chemical processing perspective, leads to exciting potential advantages. Both the waste form (the solid form in which a radionuclide is incorporated) and the geologic repository for which that waste is destined can be tailored to optimize the safety and economics of the process. A particular waste form for isolating one or more radionuclides can in principle be optimized for the geologic and geochemical conditions of a particular repository setting. Considering that a variety of geologic environments are currently being considered worldwide, including granite, clay, and salt, long-term R&D investigating the suitability in a wide range of host environments seems prudent.

Los Alamos and other DOE laboratories, in collaboration with universities, stand ready to embark on a new, leading-edge effort to tackle the considerable scientific and engineering challenges posed by the waste issue. Radionuclides in waste streams from a closed fuel cycle could be stabilized in either solid glass, metal, or ceramic waste forms that would be disposed of in mined geologic repositories, or otherwise stored for a time sufficient to allow the radiotoxicity to be reduced to safe levels. R&D and engineering studies are being conducted to guide the selection of the solid matrix and waste loadings.

The goal of this effort is to design waste forms that are resistant to radiation damage and dissolution and mobilization of the waste in the selected environment. A long-term experimental and modeling program is required to achieve an ability to understand and ultimately predict the long-term behavior of these new waste forms in a geologic environment. Fundamental understanding of the reactive dissolution of the waste, as affected by self-irradiation and elemental transformations due to radioactive decay, is required to predict the long-term durability of a given waste form exposed to a given set of physical and geochemical conditions.

4.) *Safeguards*: Advanced material control and safeguards technologies to support national nonproliferation objectives can enable the safe and secure expansion of nuclear energy in the U.S. and globally. Research on an enhanced system will build on existing safeguards technologies, many of which were created at Los Alamos, to enable near-real time knowledge extraction of facility operations and global nuclear material management. These technologies will include development of high reliability, remote and unattended surveillance systems.

It is important to note that the United States leads the world in developing safeguard technologies. As an example, the International Atomic Energy Agency sends every new inspector to LANL for required training. Inspectors who have responsibility for advanced fuel cycle facilities return to LANL for advanced training. The experimental facilities at the Los Alamos Neutron Science Center can provide data to enable new instrumental techniques. Hot cell facilities at the Chemistry and Metallurgy Research building can provide an integrated material control & accountability and safeguards R&D test bed in an environment where iterative development can occur in an uncontaminated environment. In addition, computational capabilities developed under the stockpile stewardship program can be brought to bear to bring new levels of modeling and simulation to this area.

5.) *Modeling and Simulation:* The advanced modeling and simulation tools developed for the nuclear weapons program at the national labs by NNSA's Advanced Simulation and Computing (ASC) program are now being applied to GNEP. Systems analysis studies help define and quantify the benefits and disadvantages of various deployment options for an expanded nuclear energy system, from uranium mining, to fuel fabrication, to reactor construction, to emplacement of wastes in a repository.

The modeling and simulation tools take advantage of the tremendous computer power and computational physics approaches that were developed for ASC. Several simulation tools required minimal modifications to address the needs of nuclear fuel manufacturing. As an example, the same tools used for simulations of plutonium alloy casting (TELLURIDE at LANL) are now employed for optimizing the casting of plutonium-based metal fuels. A number of ASC codes (CHAD at LANL and DIABLO at Lawrence Livermore National Laboratory) are currently being updated to include the models and numerical methods necessary for simulations of coupled phenomena in the nuclear fuel element, such as heat transport, diffusion of fission products, and thermo-mechanical deformation. This effort is aimed at developing an advanced fuel performance code.

In parallel, fundamental studies are being carried out at national laboratories to advance the understanding of irradiation effects on nuclear fuels and reactor structural materials. The studies are focused on predicting the changes in the thermal, mechanical, and chemical properties of the materials as a function of burnup (cumulative radiation) to determine the most probable causes of fuel element failure as well as the most probable time when the failure will occur. The fundamental studies are also critical in evaluating and optimizing new fuel types, such as the multi-component, transuranic oxide fuels (UPu-Np-Am-O).

Similar efforts are directed at simulating coupled phenomena in the nuclear reactor core. The complexity of these studies is increased by the necessity to incorporate neutron fluxes and their effect on the properties of the fuel and structural materials. LANL gained international recognition for developing one of the most advanced Monte Carlo simulations tools, the MCNP (Monte Carlo N-Particle Transport) program. Building on that, the simulations of the thermal-hydraulics in thermal and fast reactors revealed the necessity for new, advanced algorithms and high performance computational platforms. Recent simulations of ASC codes performed on the first components of the Roadrunner supercomputer at LANL demonstrated an important increase in computational capability. Besides benefiting the traditional LANL core programs, the increase in computational speed will benefit the complex, large-scale nuclear reactor simulations and lead to truly predictive accident scenario capabilities.

Although the thermo-chemistry of traditional actinide and fission products separation methods (UREX and PUREX) is well established, there are no advanced computational tools able to simulate the entire separation process. This area would benefit from intense research aimed at optimizing the separation process and reducing the risk of nuclear proliferation. A similar thermo-chemical approach is used in assessing the behavior of nuclear waste at the main US repositories. Comprehensive, fundamental models of chemical reactions between the waste and the environment have been developed at LANL and will serve as the basis for advanced simulation tools, able to predict the behavior of the waste over long periods of time.

#### CONCLUSION

In conclusion, the GNEP technology development program lays out a reasonable approach for closing the fuel cycle. With adequate R&D and critical investments in laboratory infrastructure, basic processes and systems can be demonstrated at rea-

sonable scale and on a timetable consistent with the GNEP plan. Much of the infrastructure exists within national laboratories; for example the large hot cells in LANL's Chemistry and Metallurgy Research facility are perfectly suited for investigations of materials that have experienced radiation fatigue. There are no technological show stoppers to closing the fuel cycle, and providing a global approach to a major expansion of nuclear energy.

Thank you, and I look forward to your questions.

The CHAIRMAN. Thank you very much.  
Mr. Bunn, go right ahead.

**STATEMENT OF MATTHEW BUNN, BELFER CENTER FOR  
SCIENCE AND INTERNATIONAL AFFAIRS, HARVARD UNIVERSITY,  
CAMBRIDGE, MA**

Mr. BUNN. All right. Thank you very much. Mr. Chairman and members of the committee, it's an honor to be here today to discuss the Global Nuclear Energy Partnership.

I'm a supporter of nuclear energy, and of a strong nuclear R&D program, and there are several concepts in the GNEP umbrella, which would reduce proliferation risks and deserve support. But building a commercial-scale reprocessing plant in the near-term would be a costly mistake that would increase proliferation risks, rather than reducing them.

Since 1976, the U.S. message to other countries has been that reprocessing is unnecessary. Now with GNEP, the message is, "Reprocessing is essential to the future of nuclear energy, but we're going to keep the technology away from you." I think that will make it more difficult to meet President Bush's goal of limiting the spread of reprocessing technology.

DOE argues, on the contrary, the GNEP will provide assured fuel services that will give countries incentives not to build their own enrichment and reprocessing facilities. This is a worthwhile objective, but U.S. reprocessing is irrelevant to providing assured supply of fresh fuel, and is not necessary for taking back limited quantities of spent fuel from countries developing nuclear power for the first time.

DOE argues that the new processes, such as the UREX-plus family, will be proliferation-resistant. But having other countries pursue UREX-plus, or power processing, would be only a modest improvement over the traditional PUREX reprocessing technology. Because deploying these processes would also give States experience and infrastructure that would be extremely helpful to a nuclear weapons program.

Senator DOMENICI. Would you state that again?

Mr. BUNN. I would say that having a UREX-plus plant would give them experience and infrastructure that would be extremely helpful for producing plutonium for a nuclear weapons program, it would make that program cheaper and quicker for them to accomplish.

With respect to potential theft and diversion, DOE emphasizes that GNEP processes will not produce pure, separated plutonium. This is a slogan, not an analysis. Pure plutonium is not needed for a nuclear weapon. Nuclear weapons could be made directly from the roughly 50/50 plutonium/uranium mix proposed in the COAX process, for example, or the plutonium could be separated in a simple glove box. Any State or group capable of doing the technically

challenging job of making the nuclear bomb from pure plutonium would be likely to be able to do the much simpler job of getting pure plutonium from this plutonium/uranium mix.

Keeping the minor actinides and possibly some of the lantanides with the plutonium, as proposed in UREX-plus and its variants, would make the product more radioactive. But the radioactivity would be far less than needed to deter theft, particularly by suicidal terrorists.

The UREX-plus process, and pyroprocessing both take away the great mass of the uranium, and most of the radioactivity from the fission products, and are thus—result in a product that's much easier to get plutonium out of than is spent fuel that has not been reprocessed. These processes may be somewhat better than PUREX, but there can be no confidence that other countries will pursue more complex and expensive technology, just because we do.

We have heard that these technologies are likely to be more expensive, and an obvious question is who will pay these costs? Are we talking about decades of government subsidies, where onerous regulations requiring industry to pay for un-economic activities.

As, I'm sure, Professor Todreas will discuss in some detail, the advanced technologies proposed in GNEP are not yet technologically mature. It would not be a sign of U.S. leadership to build, essentially, a near-copy of what already exists in France and Japan, which is what we know how to build today.

As one GNEP participant put it to me, "I could build you a 1975 Cadillac, but I don't know why you would want one."

Fortunately, there's no need for reprocessing now. Recent studies indicate that the technical capacity of the Yucca Mountain repository is far larger than the legislated capacity, large enough to support a growing nuclear enterprise for many decades to come.

Dry casks offer a safe and proven technology that makes it possible to store spent fuel for decades at low cost, allowing time for technology to develop.

What, then, should be done? First, I recommend that Congress reject proposals for near-term construction of commercial reprocessing plants, following the bipartisan advice of the National Commission on Energy Policy and of the recent National Academy of Science's review.

Second, Congress should re-direct GNEP to focus on a broad program of long-term research on approaches to overcome the liabilities of both the closed cycle and the open cycle, focusing on a wide range of different technologies. It would be a mistake to down-select now, and focus only on technologies that could be deployed in the near term.

Third, Congress should increase funding for some of the positive elements of GNEP and direct the Administration to devote greater attention to pushing them forward. This includes the fuel leasing approach, including take-back of spent fuel, which could allow countries to avoid establishing repositories of their own and give them a very strong incentive to rely on international fuel supply, rather than building their own enrichment and reprocessing facilities.

It includes small, factory-built nuclear battery approaches to nuclear reactors, it could be deployed in foreign countries and gen-

erate electricity for a period of years, and then be brought back, which would make it possible to have broadly deployed nuclear energy with minimal proliferation risks.

It includes greater efforts than we have pursued so far to develop the advanced safeguards that have been talked about, and to reduce the stockpiles of separated plutonium around the world.

Fourth, Congress and the Administration should work together to establish cost-effective dry cask storage approaches, to address the spent fuel problems that have resulted from the continuing delays at Yucca Mountain.

Finally, Congress and the Administration should work together to redouble our efforts to stem the spread of nuclear weapons, ranging from resolving the crisis with Iran and North Korea, to securing nuclear stockpiles around the world, to stopping black market nuclear networks.

That concludes my statement, and I'd be happy to take your questions.

[The prepared statement of Mr. Bunn follows:]

PREPARED STATEMENT OF MATTHEW BUNN, BELFER CENTER FOR SCIENCE AND  
INTERNATIONAL AFFAIRS, HARVARD UNIVERSITY, CAMBRIDGE, MA

Mr. Chairman and members of the subcommittee, it is an honor to be here today to discuss the Global Nuclear Energy Partnership (GNEP). I should emphasize that I am expressing my own views, which should not be attributed to Harvard University or to any committees or organizations of which I am a member. I have been asked to focus on the proliferation and security issues.<sup>1</sup>

A key GNEP goal is to expand global reliance on nuclear energy without increasing proliferation risks. Controlling the spread of enrichment and reprocessing—the technologies that make it possible to produce nuclear bomb material—is a critical part of achieving that objective.

Some elements of GNEP could make important contributions to reducing proliferation risks. Unfortunately, GNEP's heavy focus on building a commercial-scale reprocessing plant in the near term would, if accepted, increase proliferation risks rather than decreasing them.

PROLIFERATION RISKS OF NEAR-TERM U.S. REPROCESSING

The first set of proliferation risks that should be considered relates to the spread of nuclear weapons-related technologies to additional states. Since 1976, the U.S. message has been, in effect, “reprocessing is unnecessary; we, the country with the world's largest nuclear fleet, are not doing it, and you do not need to either.” Now, with GNEP, the message is “reprocessing is essential to the future of nuclear energy, but we will keep the technology away from all but a few states.”<sup>2</sup> This shift is likely to make it more difficult to achieve President Bush's goal of convincing other countries not to build their own reprocessing facilities. It has already led

<sup>1</sup>For a more comprehensive account of the issues surrounding near-term reprocessing in the United States, see Matthew Bunn, “Assessing the Benefits, Costs, and Risks of Near-Term Reprocessing and Alternatives,” testimony before the Subcommittee on Energy and Water, Committee on Appropriations, U.S. Senate, 14 September 2006, available as of 12 November 2007 at [www.belfercenter.org/publication/3222/](http://www.belfercenter.org/publication/3222/); see also Frank von Hippel, Managing Spent Nuclear Fuel in the United States: The Illogic of Reprocessing (Princeton, N.J.: International Panel on Fissile Materials, Research Report 3, January 2007, available as of 11 November 2007 at [http://www.fissilematerials.org/ipfm/site\\_down/ipfmresearchreport03.pdf](http://www.fissilematerials.org/ipfm/site_down/ipfmresearchreport03.pdf)). For broader assessments of the future of nuclear energy that come to similar conclusions, see John Deutch and Ernest J. Moniz, co-chairs, The Future of Nuclear Power: An Interdisciplinary MIT Study (Cambridge, MA: Massachusetts Institute of Technology, 2003, available as of 12 November 2007 at <http://web.mit.edu/nuclearpower/>); and Keystone Center, Nuclear Power Joint Fact-Finding (Keystone, Colo: Keystone Center, June 2007, available as of 12 November 2007 at [http://www.keystone.org/spp/documents/FinalReport\\_NJFF6\\_12\\_2007\(1\).pdf](http://www.keystone.org/spp/documents/FinalReport_NJFF6_12_2007(1).pdf)).

<sup>2</sup>This formulation is adapted from Frank von Hippel, “GNEP and the U.S. Spent Fuel Problem,” congressional staff briefing, 10 March 2006.



South Korea to express new interest in reprocessing, and France to begin considering exports of reprocessing plants to non-nuclear weapon states.<sup>3</sup>

While it is often said that the rest of the world did not listen to us on reprocessing, the evidence suggests the opposite. Since Japan launched its first reprocessing plant in 1977, no other non-nuclear-weapon state has begun reprocessing; Argentina, Belgium, Brazil, Germany, and Italy have shut down their pilot-scale reprocessing plants; and Taiwan and South Korea have abandoned their laboratory-scale reprocessing efforts (both of which were associated with secret nuclear weapons programs).<sup>4</sup> Japan is now the only non-nuclear weapon state that reprocesses spent fuel on its territory.

Department of Energy (DOE) officials respond by arguing that under GNEP, the United States will provide assured fuel services that will reduce countries' incentives to build their own enrichment and reprocessing plants. That is a worthwhile objective, and as I will discuss later, programs to take away countries' spent nuclear fuel could be a dramatic new incentive for them to rely on the international nuclear fuel market rather than building their own facilities. But U.S. reprocessing is irrelevant to providing assured fresh fuel supply—the principal focus so far—and if the United States or other countries are going to take back limited quantities of spent fuel from new countries developing nuclear energy, there is no requirement that this fuel be reprocessed.

It is important to pursue these objectives carefully, so as to follow the dictum “first, do no harm.” Ironically, the period since President Bush’s 2004 speech in which he laid down the objective of preventing the spread of enrichment and reprocessing technologies to countries that did not already operate such plants has seen the greatest explosion of interest in uranium enrichment in the nuclear age, with states such as South Africa, Argentina, Australia, Canada, Ukraine, and Belarus suddenly expressing renewed interest. If states perceive that a new line is to be drawn between technology “haves” and “have nots”—a perception that early GNEP presentations on dividing the world into “supplier states” and “recipient states” contributed to—they will rush to try to ensure that they are on the “have” side of the line.

DOE officials then argue that the reprocessing approaches to be pursued in GNEP are “proliferation resistant.” But having other countries pursue processes in the UREX+ family rather than PUREX would be only a modest improvement. While UREX+ facilities could be designed so that modifying them to separate pure plutonium would be moderately costly and observable, states with UREX+ facilities would gain experience, infrastructure, and materials that would allow them to produce plutonium for nuclear weapons more rapidly and at less cost. For these reasons, the State Department has publicly expressed the view that UREX+ facilities, like PUREX facilities that separate pure plutonium, must remain “forever confined” to a small number of supplier states.<sup>5</sup> That is a challenging objective, which will be made more difficult by the United States emphasizing the importance of reprocessing.

Similarly, non-nuclear weapon states operating pyroprocessing facilities would gain in-depth experience with plutonium processing and metallurgy, which would be very helpful to a nuclear weapons program. The United States should understand that pyroprocessing is a form of reprocessing, and the United States should oppose the spread of this technology to additional countries just as it opposes the spread of aqueous reprocessing technologies. Recent reports suggesting that the United States is willing to support pyroprocessing in South Korea are particularly troubling, as South Korea, in addition to its past reprocessing-based nuclear weapons program, also has an agreement with North Korea prohibiting enrichment and reprocessing on the Korean peninsula. A South Korean move away from that agree-

<sup>3</sup> On South Korea, see, for example, Mark Hibbs, “ROK to Chart Fuel Cycle Policy Course Beyond Wait-and-See,” *NuclearFuel*, 23 April 2007; on the French export ideas, see Ann MacLachlan, “Areva Dual-Track Strategy Aimed at Two Reprocessing Plants,” *NuclearFuel*, 3 July 2006. Areva, the state-owned French nuclear conglomerate, is quoted as saying that GNEP “boosted” its plans for exporting reprocessing plants.

<sup>4</sup> For a discussion, see von Hippel, *Managing Spent Fuel in the United States*, p. 20. Other than Japan, the major commercial reprocessing facilities in the world are in nuclear weapon states: France, the United Kingdom, and Russia. Since 1976, many of their customers (such as Germany and Sweden, among others) have joined the United States in abandoning reprocessing in favor of direct disposal. In general, the poor economics of reprocessing have driven decisions more than U.S. policy.

<sup>5</sup> James Timbie, U.S. Department of State, remarks to an open meeting of the U.S. National Academy of Sciences-Russian Academy of Sciences Committee on Internationalization of the Nuclear Fuel Cycle, 17 October 2006.

ment would likely make elimination of North Korea's nuclear weapons program more difficult to achieve.

Another difficulty is that these processes may make it easier for states to divert a significant quantity of plutonium without detection by international inspectors. Nuclear material accounting for safeguards is already an immense challenge at traditional PUREX reprocessing plants that separate pure plutonium, with accounting uncertainties in the range of 1 percent at plants processing 6–10 tons of plutonium every year. By keeping a variety of radioactive materials with the plutonium, UREX+ and pyroprocessing approaches will make accurate nuclear material accounting for safeguards substantially more difficult, forcing a greater reliance on containment and surveillance.<sup>6</sup>

A second set of proliferation issues focuses on possible theft of plutonium by sub-national groups. While reactor-grade plutonium would not be the preferred material for making nuclear bombs, it does not require advanced technology to make a bomb from reactor-grade plutonium: any state or group that could make a bomb from weapon-grade plutonium could make a bomb from reactor-grade plutonium.<sup>7</sup> Despite the remarkable progress of safeguards and security technology over the last few decades, processing, fabricating, and transporting tons of weapons-usable separated plutonium every year—when even a few kilograms is enough for a bomb—inevitably raises greater risks than not doing so. Indeed, while many of the stocks of civil plutonium that have built up are well-guarded, critics have argued that some operations in the civilian plutonium industry are potentially vulnerable to nuclear theft.<sup>8</sup>

The administration has acknowledged that the huge stockpiles of weapons-usable separated civil plutonium built up as a result of traditional PUREX reprocessing (now roughly equal to all world military plutonium stockpiles combined, remarkably) “pose a growing proliferation risk” that “simply must be dealt with.”<sup>9</sup>

In claiming that GNEP processes would pose lower risks, DOE officials have repeatedly emphasized that GNEP approaches will produce “no pure plutonium.” Remarkably, DOE reports that this was the “only requirement” the department imposed on the technologies industry could propose for near-term construction.<sup>10</sup> But “no pure plutonium” is a slogan, not an analysis of proliferation resistance. Pure plutonium is not needed to make a nuclear bomb.

The COEX process proposed by some for a near-term reprocessing plant, for example, which extracts the plutonium and some of the uranium together, poses nearly as much risk as processes that separate pure plutonium. The uranium-plutonium mix could be used directly in a bomb, or the plutonium could readily be separated even in a crude, jerry-rigged glove box, using commercially available equipment and materials. Any state or group capable of doing the technically challenging job of making a nuclear bomb from pure plutonium would likely be able to do the simpler job of getting pure plutonium from a plutonium-uranium mix without fission products. For these reasons, under either Nuclear Regulatory Commission (NRC) or

<sup>6</sup>For a discussion, see Edwin S. Lyman, “The Global Nuclear Energy Partnership: Will it Advance Nonproliferation or Undermine It?” in Proceedings of the Institute for Nuclear Materials Management 47th Annual Meeting, Nashville, Tennessee, 16–20 July 2006 (Northbrook, IL: INMM, 2006, available as of 11 November 2007 at <http://www.npec-web.org/Essays/20060700-Lyman-GNEP.pdf>); see also von Hippel, *Managing Spent Fuel in the United States*, pp. 23–24.

<sup>7</sup>For an authoritative unclassified discussion, see Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives, DOE/NN-0007 (Washington DC: U.S. Department of Energy, January 1997), pp. 38–39.

<sup>8</sup>Ronald E. Timm, *Security Assessment Report for Plutonium Transport in France* (Paris: Greenpeace International, 2005; available as of 12 November 2007 at [www.greenpeace.fr/stop-plutonium/en/TimmReportV5.pdf](http://www.greenpeace.fr/stop-plutonium/en/TimmReportV5.pdf)).

<sup>9</sup>Samuel Bodman, “Carnegie Endowment for International Peace Moscow Center: Remarks as Prepared for Secretary Bodman” (Moscow: U.S. Department of Energy, 16 March 2006; available at <http://energy.gov/news/3348.htm> as of 12 November 2007). This characterization seems oddly out of tune with the schedule of the administration's proposed solution, advanced burner reactors that will not be available in significant numbers to address this “growing” risk for decades. In a similar vein, the British Royal Society, in a 1998 report, warned that even in an advanced industrial state like the United Kingdom, the possibility that plutonium stocks might be “accessed for illicit weapons production is of extreme concern.” The Royal Society, *Management of Separated Plutonium* (London: Royal Society, 1998, available as of 12 November 2007 at <http://www.royalsoc.ac.uk/displaypagedoc.asp?id=18551>). The Royal Society renewed this warning and analyzed the options for action in a 2007 report. See The Royal Society, *Strategy Options for the UK's Separated Plutonium* (London: The Royal Society, September 2007, available as of 12 November 2007 at <http://www.royalsoc.ac.uk/displaypagedoc.asp?id=27169>).

<sup>10</sup>U.S. Department of Energy, Office of Nuclear Energy, “DOE Response to NAS-NRC Report Review of DOE's Nuclear Energy Research and Development Program” (Washington DC: 29 October 2007, available as of 11 November 2007 at <http://www.gnep.energy.gov/pdfs/NAS-Response.pdf>).

international guidelines, such a mixture would still be considered Category I material, posing the highest levels of security risk and requiring the highest levels of security.<sup>11</sup> When such approaches were last seriously considered in the United States three decades ago, the Nuclear Regulatory Commission concluded that “lowering the concentration of plutonium through blending [with uranium] should not be used as a basis for reducing the level of safeguards protection,” and that the concentration of plutonium in the blend would have to be reduced to ten percent or less—far less than being considered for COEX—for the safeguards advantages to be “significant.”<sup>12</sup>

For the longer term, GNEP is looking at processes such as the UREX+ family, in which the actinides and possibly some of the lanthanide fission products would stay with the plutonium. But the processing proposed in UREX+ still takes away the great mass of the uranium and the vast majority of the radiation from the fission products, making it far easier to recover plutonium from the product than from unprocessed spent fuel. Actinides with which the plutonium would be mixed, such as neptunium, are also potentially potent nuclear bomb materials. The situation for pyroprocessing is different in specifics, but not in the overall conclusion. Indeed, the plutonium-bearing materials that would be separated from aged spent fuel in either the UREX+ process or by pyroprocessing would not be radioactive enough to meet international standards for being “self-protecting” against possible theft.<sup>13</sup>

Proponents of reprocessing and recycling often argue that this approach will provide a nonproliferation benefit by consuming the plutonium in spent fuel, which would otherwise turn geologic repositories into potential plutonium mines many hundreds or thousands of years in the future. But the proliferation risk posed by spent fuel buried in a safeguarded repository is already modest; if the world could be brought to a state in which such repositories were the most significant remaining proliferation risk, that would be cause for great celebration. Moreover, this risk will be occurring a century or more from now, and if there is one thing we know about the nuclear world a century hence, it is that we know almost nothing about it. We should not increase significant proliferation risks in the near term in order to reduce already small and highly uncertain proliferation risks in the distant future.<sup>14</sup>

In short, all of the spent fuel processing approaches proposed for GNEP pose higher, not lower, proliferation risks than are posed by not processing the spent fuel at all and continuing to rely on a once-through fuel cycle. Some of these approaches do offer modest proliferation advantages compared to the traditional PUREX reprocessing approach. But there are no grounds for confidence that our pursuit of these technologies will convince other countries to phase out the PUREX processes in which they have made large investments, particularly as processes such as UREX+ add several complex steps and are therefore likely to be more expensive.

Ultimately, proliferation resistance should not be judged solely on how much material other than plutonium there may be in the product of a particular process, or how radioactive that product might be. Rather, it should be judged by a full life-cycle examination of how the deployment of such technologies by some states might affect the spread of sensitive technologies to other states; how much access to the materials, facilities, and expertise involved in the proposed fuel cycle would reduce

<sup>11</sup> See, for example, the categorizations in U.S. Nuclear Regulatory Commission, “Part 73-Physical Protection of Plants and Materials,” in Title 10, Code of Federal Regulations (Washington, D.C.: U.S. Government Printing Office; available as of 12 November 2007 at <http://www.nrc.gov/reading-rm/doc-collections/cfr/part073/full-text.html>); International Atomic Energy Agency, The Physical Protection of Nuclear Material and Nuclear Facilities, INFCIRC/225/Rev.4 (Corrected) (Vienna: IAEA, 1999; available as of 12 November 2007 at <http://www.iaea.or.at/Publications/Documents/Infircs/1999/infirc225r4c/rev4—content.html>). Any effort to define such a facility at only requiring Category II safeguards, on the basis of DOE’s starkly different (and in important respects misguided) categorization guidelines, should be firmly rejected.

<sup>12</sup> Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Safeguarding a Domestic Mixed Oxide Industry against a Hypothetical Subnational Threat, NUREG-0414 (Washington, D.C.: NRC, 1978), pp. 6.8–6.10.

<sup>13</sup> Keeping the actinides with the plutonium provides only a small fraction of the radiation level considered “self-protecting” by international standards—1 Sievert/hr at 1 meter, a standard that should itself be fundamentally reexamined in an age of suicidal terrorists. The lanthanide fission products have relatively short half-lives, and only provide substantial radiation fields if the spent fuel is processed fairly quickly after discharge. See Jungmin Kang and Frank von Hippel, “Limited Proliferation-Resistance Benefits From Recycling Unseparated Transuranics and Lanthanides From Light-Water Reactor Spent Fuel,” *Science and Global Security*, Vol. 13, pp. 169–181, 2005, available as of 12 November 2007 at [http://www.princeton.edu/~globsec/publications/pdf/13\\_3%20Kang%20vonhippel.pdf](http://www.princeton.edu/~globsec/publications/pdf/13_3%20Kang%20vonhippel.pdf).

<sup>14</sup> For a discussion, see John P. Holdren, “Nonproliferation Aspects of Geologic Repositories,” presented at the “International Conference on Geologic Repositories,” October 31–November 3, 1999, Denver, Colorado).

the time, cost, and observability of a state nuclear weapons program; and how the large-scale adoption of such a fuel cycle would affect the risks of nuclear theft and nuclear terrorism around the world.<sup>15</sup>

#### SECURITY AGAINST SABOTAGE

Construction of a large reprocessing facility using the technologies available now or in the near term would also be likely to increase risks of terrorist sabotage. While such facilities could be designed and operated with stringent anti-terrorist security measures, reducing this risk to a modest level, transporting and processing thousands of tons of intensely radioactive spent nuclear fuel inevitably involves more opportunities for terrorist mischief than leaving that spent fuel in large steel or concrete casks.

#### COSTS OF REPROCESSING AND RECYCLING

Reprocessing using technologies available now or in the near term is likely to be substantially more expensive than direct disposal of spent fuel.<sup>16</sup> The UREX+ technology now being pursued adds a number of complex separation steps to the traditional PUREX process, and would likely be even more expensive. The capital cost of fast-neutron reactors such as those proposed for GNEP has traditionally been significantly higher than that of light-water reactors. A National Academy of Sciences review of separations and transmutation technologies such as those proposed for GNEP concluded that the additional cost of recycling compared to once through for 62,000 tons of commercial spent fuel “is likely to be no less than \$50 billion and easily could be over \$100 billion.”<sup>17</sup> While spent fuel management is only a small part of the cost of nuclear energy, the proposed GNEP approach would also require construction of a large fleet of fast reactors whose capital costs—the key driver of nuclear energy costs—have always been higher than those of light-water reactors. If the capital costs of fast reactors remained significantly higher in the future, processing all U.S. spent fuel in this way would cost tens or hundreds of billions of dollars more than a once-through approach. Who will pay these costs? Are we talking about many decades of government subsidies, or onerous regulations requiring private industry to pay for uneconomic activities?

The Boston Consulting Group study outlines the hope that if new facilities could be built with a much larger capacity for only modestly more money—and would operate close to capacity throughout their lives, something no real reprocessing plant has ever done—the unit costs of reprocessing might be much reduced. But the real experience of building a plant similar to the French reprocessing plant in Japan has been unit costs several times higher than those in France, not lower; the costs of the MOX fuel plant private firms are building for DOE, also based on French technology, are also several times higher, not lower, than those of the French plants. One can argue—correctly—that each of these new plants has unique problems, but why should we expect that a new reprocessing plant in the United States would avoid similar problems? No policy-maker should make decisions about reprocessing based on an expectation that the costs will be similar to those projected in the Boston Consulting Group report.

Rather than relying solely on paper analyses, one can look at the evidence from the commercial market. The British reprocessing plant will be closed in a few years because it cannot get enough contracts to keep running; the French and Russian reprocessing plants are operating at far less than capacity because of a lack of contracts; to pay the huge costs of the Japanese reprocessing plant, Japanese utilities insisted on a government bailout in the form of a wires charge that will increase

<sup>15</sup>For a discussion, see Matthew Bunn, “Proliferation-Resistance (and Terror-Resistance) of Nuclear Energy Systems” lecture, Massachusetts Institute of Technology, 1 May 2006, available at [http://www.belfercenter.org/files/proliferation\\_resist\\_lecture06.pdf](http://www.belfercenter.org/files/proliferation_resist_lecture06.pdf) as of 12 November 2007. For a more elaborate methodology, see Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy Systems (Paris: Gen. IV International Forum, November 2006, available as of 12 November 2007 at <http://www.gen-4.org/Technology/horizontal/PRPPEM.pdf>).

<sup>16</sup>Matthew Bunn, Steve Fetter, John P. Holdren, and Bob van der Zwaan, *The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel* (Cambridge, MA: Project on Managing the Atom, Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, December 2003, available as of 12 November 2007 at <http://www.belfercenter.org/files/repro-report.pdf>).

<sup>17</sup>U.S. National Research Council, *Committee on Separations Technology and Transmutation Systems, Nuclear Wastes: Technologies For Separation and Transmutation* (Washington, D.C.: National Academy Press, 1996), p. 7. Note that these figures are expressed in 1992 dollars; in 2006 dollars, the range would be \$66-\$133 billion.

the price of electricity for all users in Japan for many years to come. When utilities have a choice, they do not choose to reprocess their fuel.

#### ROOM AT YUCCA MOUNTAIN

Similarly, it is by no means clear that effective nuclear waste management and disposal in the United States will require reprocessing and recycle. Recent studies indicate that the technical capacity of the Yucca Mountain repository is far larger than the legislated capacity—large enough to support a growing nuclear energy enterprise for many decades to come.<sup>18</sup> GNEP is likely to make it more difficult, rather than easier, to get a license for Yucca Mountain, by creating uncertainty over what, exactly, would be disposed of there, and raising the possibility that wastes from a far larger number of reactors would be emplaced there. If Yucca Mountain opens and begins operating successfully—and a repository will certainly be required whether we continue to rely on a once-through fuel cycle or shift to a closed cycle—it may well be easier to get a license for using the next ridge over for an additional repository than it will be to get political approvals and licenses for several large reprocessing plants and dozens of fast neutron reactors.

#### WHAT'S BEST FOR THE FUTURE OF NUCLEAR ENERGY?

Mr. Chairman, to be against near-term reprocessing is not the same as being against nuclear power. It is precisely because I hope for a vibrant and growing future for nuclear energy, to help cope with climate change, that I am against near-term reprocessing. Nuclear power's future will be best assured by making it as cheap, simple, safe, and proliferation-resistant as possible—and near-term reprocessing points in the wrong direction on every count.<sup>19</sup>

#### TECHNICAL MATURITY

Fortunately, there is no pressing need to move forward with construction of a reprocessing plant in the United States in the near term. Dry casks offer a safe and proven technology that makes it possible to store spent fuel for decades at low cost. As a result, there is no need to rush to make these decisions—we can make these decisions more responsibly in the decades to come, when technology has developed further and economic, security, and political circumstances have clarified. What is needed now is patient R&D and in-depth systems analysis, rather than a rush to build commercial-scale facilities. As Richard Garwin has put it, by picking winners prematurely, the proposed GNEP approach “would launch us into a costly program that would surely cost more to do the job less well than would a program at a more measured pace guided by a more open process.”<sup>20</sup>

It would certainly not be a sign of U.S. leadership to decide now to build a reprocessing plant little different from what France, Russia, the United Kingdom, and Japan have already built—to build, as one GNEP participant put it to me, a 1975 Cadillac. Rather, it would lock the United States in to spending many billions of dollars on decades-old technologies whose high costs and proliferation risks are already well known, and which are already failing to win contracts in the commercial marketplace. The idea of sending spent fuel from decommissioned U.S. reactors to France to be reprocessed, as DOE is reportedly considering,<sup>21</sup> has even less merit,

<sup>18</sup> Program on Technology Innovation: Room at the Mountain—Analysis of the Maximum Disposal Capacity for Commercial Spent Nuclear Fuel in a Yucca Mountain Repository (Palo Alto, Calif: Electric Power Research Institute, May 2006, available as of 12 November 2007 at <http://www.epriweb.com/public/000000000001013523.pdf>).

<sup>19</sup> For a similar argument that the GNEP approach “threatens to set back the nuclear revival,” see, for example, Richard Lester, “New Nukes,” *Issues in Science and Technology*, Summer 2006, pp. 39–46. For earlier discussions of this point, see, for example, John P. Holdren, “Improving US Energy Security and Reducing Greenhouse-Gas Emissions: The Role of Nuclear Energy,” testimony to the Subcommittee on Energy and Environment, Committee on Science, U.S. House of Representatives, 25 July 2000, available as of 12 November 2007 at <http://www.belfercenter.org/publication/3244/>; and Matthew Bunn, “Enabling A Significant Future For Nuclear Power: Avoiding Catastrophes, Developing New Technologies, Democratizing Decisions—And Staying Away From Separated Plutonium,” in *Proceedings of Global '99: Nuclear Technology-Bridging the Millennia*, Jackson Hole, Wyoming, August 30–September 2, 1999 (La Grange Park, Ill.: American Nuclear Society, 1999, available as of 12 November 2007 at [www.belfercenter.org/publication/2014/](http://www.belfercenter.org/publication/2014/)).

<sup>20</sup> Richard L. Garwin, “R&D Priorities for GNEP,” testimony to the U.S. House of Representatives, Committee on Science, Subcommittee on Energy, 6 April 2006, available as of 12 November 2007 at [www.fas.org/rig/060406-gnep.pdf](http://www.fas.org/rig/060406-gnep.pdf).

<sup>21</sup> Jeff Beatie, “DOE Pushing to Recycle Closed Plants’ Spent Fuel,” *Energy Daily*, 7 November 2007.

and should be soundly rejected. The reprocessing would cost well over a billion dollars, far more than continuing to store this fuel where it is, and would simply add to the multi-billion dollar problem of excess plutonium the United States already has. DOE has correctly identified large global stockpiles of separated plutonium as a dangerous problem; dealing with that problem by reprocessing more plutonium is like using gasoline to put out a fire.

The recent National Academy of Sciences review has provided an excellent discussion of just how premature it would be to build commercial-scale facilities now, unanimously recommending against proceeding with a GNEP program focused on near-term large-scale construction. As they concluded: "There is no economic justification to go forward with this program at anything approaching commercial scale. Continued research and development are the appropriate level of activity, given the current state of knowledge." I urge the Committee to hear from the National Academy panel, to get the insights gained from their in-depth examination of the GNEP program in the context of other nuclear R&D.

#### POSITIVE ELEMENTS OF GNEP

As I mentioned at the outset, other elements of GNEP could be significant steps to reduce the proliferation risks of nuclear energy. Unfortunately, these other elements have not received comparable emphasis and funding in the program to date.

Fuel leasing.—First, providing assured fuel services, so that countries have strong incentives not to build enrichment or reprocessing plants of their own, is a potentially important idea.<sup>22</sup> The current emphasis is primarily on assured supplies of fresh nuclear fuel; while this is an important goal, it should be recognized that the commercial market already provides high assurance of fuel supply (except for countries that are special cases outside of or in violation of global nonproliferation norms, such as Iran and India). Less need to build enrichment or reprocessing fuel leasing—that is, providing fresh fuel to countries with a promise to take the spent fuel away—would allow countries to enjoy the benefits of nuclear energy without having to build repositories. This would create a powerful new incentive for countries starting new nuclear energy programs to rely on foreign fuel supply rather than building enrichment and reprocessing of their own. (Note that existing reprocessing services offered by Britain and France, which require that the wastes be sent back to the customer, would not have this advantage.) Moreover, widespread fuel leasing would mean that plutonium-bearing spent fuel need not build up in countries all over the world. There are obvious political problems with one country taking another country's spent fuel, but we should be working to address these problems—as we have in the case of taking back spent research reactor fuel. It is important to note that take-back of modest quantities of foreign spent fuel from the small numbers of reactors likely to be built in coming decades in new nuclear countries would not in any way require that this fuel be reprocessed. Russia has already passed legislation that allows it to enter the fuel leasing business, and signed a contract with Iran that requires all of Iran's spent fuel to be shipped back to Russia. Other countries have considered being hosts for international waste storage facilities. It only takes one of the world's 190 countries to agree to host an international repository (and if one country launched such an effort successfully, others might decide to compete with them in that highly profitable business). The country providing the fresh fuel and the country accepting the spent fuel would not necessarily have to be the same. The United States should be doing far more to make this vision a reality.<sup>23</sup>

Reducing stockpiles of separated plutonium.—Second, the huge global stocks of weapons-usable civilian separated plutonium—now as much as all the plutonium in all the world's nuclear weapons stockpiles—pose significant risks, and continue to grow. Building a reprocessing plant or a single demonstration fast reactor in the United States will not do much to solve that problem. The United States should be doing much more to work with other countries to ensure that all these stockpiles

<sup>22</sup>For a useful account of such fuel assurances, see Ashton B. Carter and Stephen LaMontagne, "Toolbox: Containing the Nuclear Red Zone Threat," *The American Interest*, Vol. 1, No. 3 (Spring 2006), pp. 28–40.

<sup>23</sup>See discussion of such international approaches in Chapter 4 of Matthew Bunn et al., *Interim Storage of Spent Nuclear Fuel: A Safe, Flexible, and Cost-Effective near-Term Approach to Spent Fuel Management* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, and Project on Sociotechnics of Nuclear Energy, Tokyo University, 2001; available as of 12 November 2007 at <http://www.belfercenter.org/publication/2150/>), pp. 95–116. Some of the best current work in both analyzing and promoting regional or international approaches to storage or disposal of spent fuel and nuclear waste is being done by the Arius consortium. Much of this work was available as of 12 November 2007 at <http://www.arius-world.org/>.

are secured to the highest practicable standards, to limit or phase out unneeded plutonium separation where possible, and to ensure that plans are put in place for reducing these immense stocks over time. In particular, the Bush administration should renew the talks with Russia, almost completed in the Clinton administration, concerning a 20-year moratorium on plutonium separation in both countries, and should cooperate with other countries to work out disposition paths for plutonium stockpiles for which there is no current plan for use or disposal.<sup>24</sup>

Small, exportable reactors.—Third, the concept that is sometimes called a “nuclear battery”—small reactors that might be produced in a factory, shipped to a deployment site with their fuel already included, generate electricity there for 10–20 years, and then be shipped back to the factory with their spent fuel—could make it possible to have widespread use of nuclear energy with little spread of sensitive materials and expertise and few proliferation risks. Within GNEP, even the small level of funding devoted to “small and medium reactors” is largely devoted to medium-sized reactors that could not be factory-built in this way. GNEP should devote higher priority to R&D on nuclear battery concepts, and particularly to approaches that might reduce their costs—currently the main barrier to implementing this approach.

Advanced safeguards development.—Fourth, as the American Physical Society has pointed out, the United States needs a major reinvestment in safeguards and security technologies to support a new nuclear era.<sup>25</sup> DOE is taking the first steps in that direction, but much more needs to be done.

#### RECOMMENDATIONS

What, then, should be done?

First, I recommend that Congress follow the bipartisan advice of the National Commission on Energy Policy;<sup>26</sup> the advice of the recent National Academy of Sciences review of GNEP;<sup>27</sup> and the advice of the American Physical Society study of nuclear energy and nonproliferation,<sup>28</sup> by rejecting proposals to spend many billions of dollars on near-term construction of a commercial-scale reprocessing plant and a commercial-scale fast reactor in the United States. The Committee would be hard-pressed to find any independent scientific or engineering group that believes such construction is a good idea in the near term.

Second, Congress should redirect GNEP to focus on long-term research on (a) advanced technologies that might have the potential to overcome the large liabilities of past reprocessing and recycling approaches; (b) improved approaches to once-through systems; and (c) in-depth studies of the real repository capacity likely to be available in different scenarios and of global uranium resources. This should include a much broader set of reactor and spent fuel processing technologies than GNEP is currently pursuing; it would be a mistake to down-select and focus only on technologies that could be deployed soon, when other technologies may have more long-term promise.<sup>29</sup> As improved recycling and once-through technologies develop, we should regularly re-examine which of them appear to offer the best combination of cost, safety, security, proliferation-resistance, and sustainability. At the

<sup>24</sup> For a discussion, see Matthew Bunn and Anatoli Diakov, “Disposition of Excess Plutonium,” in *Global Fissile Materials Report 2007* (Princeton, NJ: International Panel on Fissile Materials, October 2007, available as of 12 November 2007 at [http://www.fissilematerials.org/ipfm/site\\_down/gfmr07.pdf](http://www.fissilematerials.org/ipfm/site_down/gfmr07.pdf)), pp. 33–42. The Royal Society’s report, *Strategy Options for the UK’s Separated Plutonium*, outlines approaches that could be pursued for the United Kingdom’s huge stock of separated civilian plutonium. The United States should encourage all countries with military or civil stockpiles of excess separated plutonium to bring unneeded separation of plutonium to an end, undertake similar examinations of their options, and implement approaches to safe and secure disposition of these stockpiles as rapidly as practicable.

<sup>25</sup> Nuclear Energy Study Group, American Physical Society Panel on Public Affairs, *Nuclear Power and Proliferation Resistance: Securing Benefits, Limiting Risk* (Washington, D.C.: American Physical Society, May 2005, available as of 12 November 2007 at <http://www.aps.org/policy/reports/popa-reports/proliferation-resistance/upload/proliferation.pdf>).

<sup>26</sup> National Commission on Energy Policy, *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America’s Energy Challenges* (Washington, D.C.: National Commission on Energy Policy, December 2004, available as of 12 November 2007 at [http://www.energycommission.org/files/contentFiles/report\\_noninteractive\\_44566feaabc5d.pdf](http://www.energycommission.org/files/contentFiles/report_noninteractive_44566feaabc5d.pdf)), pp. 60–61.

<sup>27</sup> Committee on Review of DOE’s Nuclear Energy Research and Development Program, *Review of DOE’s Nuclear Energy Research and Development Program* (Washington, D.C.: National Academy Press, October 2007, available as of 12 November 2007 at <http://www.nap.edu/catalog/11998.html>).

<sup>28</sup> APS, *Nuclear Power and Proliferation Resistance*.

<sup>29</sup> For a discussion, see Garwin, “R&D Priorities for GNEP.” For a discussion of R&D that should be pursued on improved once-through options, see Deutch, Moniz, et al., *The Future of Nuclear Power*.

same time, we should not allow an expansion of nuclear R&D to overwhelm R&D on other promising energy technologies: the United States urgently needs to undertake expanded investments in a wide range of energy R&D.

Third, Congress should increase the funding for the positive elements of GNEP I have enumerated, and direct the administration to devote greater attention to pushing them forward. On these points, I believe the approach proposed by the Senate Energy and Water Appropriations Committee is a major step in the right direction.

Fourth, Congress and the administration should work to establish cost-effective dry cask storage approaches to address the spent fuel storage problems and costs that have resulted from continuing Yucca Mountain delays, including at least a small amount of centralized storage to address problems at decommissioned reactors.<sup>30</sup> Whatever option for spent fuel disposal or processing we pursue, additional interim storage capacity will be needed. Storing spent fuel in dry casks leaves all options open for the future, as technology develops and political and economic circumstances change. (Indeed, since the Yucca Mountain repository will remain open for a century or more, even direct disposal will leave all options open for a long time to come.) At least some centralized storage capacity is needed to address particular needs; whether nearly all of the spent fuel should be moved to a centralized away-from-reactor site or site depends on a number of factors that require further analysis. Here, too, we should not let frustration with the current state of affairs prevent us from taking the time to get it right: a rushed process for siting and licensing such facilities is a recipe for public opposition and ultimate failure, adding to the long history of failed attempts to site centralized interim storage facilities in the United States. In a 2001 study, we provided a detailed outline of a democratic and voluntary process for siting such facilities, based on approaches that had been applied successfully in siting other hazardous and unwanted facilities, and I would urge that such an approach be followed here.<sup>31</sup>

Fifth, Congress and the administration should work together to redouble U.S. efforts to stem the spread of nuclear weapons—resolving the crises with Iran and North Korea, securing nuclear stockpiles around the world, stopping black-market nuclear networks, and more.<sup>32</sup> Ultimately, this will also require reducing the demand for nuclear weapons, in part by reducing the number, roles, and readiness of our own.

The CHAIRMAN. Thank you very much.  
Dr. Todreas, why don't you go right ahead.

**STATEMENT OF NEIL E. TODREAS, EMERITUS PROFESSOR OF  
NUCLEAR SCIENCE AND ENGINEERING, MASSACHUSETTS  
INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA**

Mr. TODREAS. Good morning, Chairman Bingaman, Ranking Member Domenici, and the rest of the committee. My testimony this morning—I'm going to focus on the state of the technology required for the execution of GNEP, and I'll make three principle points.

The first is that I believe we need an R&D program to evaluate the potential of the closed cycle as an important national under-

<sup>30</sup>For recent discussions, see, for example, American Physical Society, Nuclear Energy Study Group, Consolidated Interim Storage of Commercial Spent Nuclear Fuel: A Technical and Programmatic Assessment (College Park, MD: American Physical Society, February 2007, available as of 12 November 2007 at <http://www.aps.org/policy/reports/popa-reports/upload/Energy-2007-Report-InterimStorage.pdf>); National Commission on Energy Policy, Energy Policy Recommendations to the President and the 110th Congress (Washington, D.C.: National Energy Commission, April 2007, available as of 12 November 2007 at [http://energycommission.org/files/contentFiles/NCEP\\_Recommendations\\_April\\_2007\\_4656f9759c345.pdf](http://energycommission.org/files/contentFiles/NCEP_Recommendations_April_2007_4656f9759c345.pdf)), pp. 21-22; and Keystone Center, Nuclear Power Joint Fact-Finding, pp. 75-79.

<sup>31</sup>Bunn et al., Interim Storage of Spent Nuclear Fuel, pp. 95-116.

<sup>32</sup>For a reasonable first cut at an agenda of steps to be taken, see George Perkovich et al., Universal Compliance: A Strategy for Nuclear Security (Washington, D.C.: Carnegie Endowment for International Peace, 2005; available at <http://www.carnegieendowment.org/files/UC2.FINAL3.pdf> as of 13 May 2007). For an agenda of steps to be taken specifically on preventing nuclear terrorism, see Matthew Bunn, Securing the Bomb 2007 (Cambridge, Mass.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, September 2007, available as of 12 November 2007 at [http://www.nti.org/e\\_research/securingthebomb07.pdf](http://www.nti.org/e_research/securingthebomb07.pdf)).



taking. I believe this for two reasons. First, to ensure national influence on the global evolution of fuel cycle technology; and two, creating technologies, that is separations, fuel fabrication, transmutation and reprocessing, sufficient to demonstrate that nuclear technology can recycle its own spent fuel if we call upon it to do so.

You've heard of the three GNEP facilities, regarding those, a major decision for the Light Water Spent Fuel Center, and the fast reactors, the appropriate scale of facilities.

The second point I'd make is to agree with the case being made for initial construction for smaller, engineering-scale facilities. Again, for two reasons: caution in the scale-up from the expected bench scale success is very prudent, and we need a flexible and dedicated radiation test bed for transition fuel development and qualification, test bed.

Now, regarding the technologies themselves, I'll start with separations of spent light water fuel. You've heard there are—the UREX-plus process, and there are two commercially controlled processes.

The UREX-plus suite, an important feature of that is it's a series of processes in which you can extract various actinides and fission products, either individually, to deal with them separately, or in a group fashion, which secures the product. No free plutonium, plutonium poisoned, effectively.

As of this summer, UREX+1a had been demonstrated relatively successfully at bench scale, but only over short times, and with fresh solvents. What does that mean? That means processed chemistry over the long-term hasn't been yet established, and scale-up not yet initiated. This development will take approximately till 2012 to complete the bench scale process development and position us for the next step.

Among the key requirements being developed to measure this process, significantly is the efficiency of separation, and the associated acceptable losses of actinide and spent fission products to waste streams. Why is this important? Because you must control the losses, so that you avoid burdening, rather than assisting, spent fuel waste management.

For transition fuels, we have a significant fabrication, and the radiation program needed. The irradiation program must prove that we can develop transmutation fuel that can go into a reactor and give us trouble-free operation. That means no failures. That's going to require operation of core loads of transmutation fuel in fast reactor environments with failure-free operation. That will be very difficult for the commercial industry to accept in a commercial reactor, and that's why I advocate a test reactor.

The computation and simulation activity has been mentioned, I hope and expect that the time and the cost of irradiations of transmutation fuels can be significantly decreased through a good, profitable simulation program. Because we can model the fuel, and then exercise real—faster than real-time computation to reduce the time required to develop these fuels with computers calibrated by experience, rather than fully in irradiation facilities.

Finally, turning to the reactor, the fast reactor, we've got to develop fast reactors with safety characteristics that are firm, that

can be licensed, and with capital and costs of fast reactors, that can gain commercial acceptance. DOE has properly engaged the industry to assist on this, and there are important system studies underway to set the requirements for these reactors.

System studies are broader than that, however, which gets to my third point. We should evaluate a thermal recycle program component which has the ability or the potential to accelerate the start of transmutation of true materials in thermal reactors, and reduce the number of fast reactors needed for ultimate disposal of transmutation fuels.

So, in conclusion, let me make several points. The development of the technology as you've heard across the board, here, is a large and demanding task. Significant activity is underway, working through the technical challenges. I agree, no insurmountable barriers exist, however, the scale, ownership, timing and ultimate cost of the GNEP facilities as strategic questions, their answer depends on many factors, but among them, importantly, is the continued progress and results of the development program.

The three points I made were, that an R&D program on the closed cycle is important as a national priority; facilities should be developed and built first, at smaller engineering scale; and finally, thermal recycle with inert matrix fuel—there are various thermal recycle approaches—but with inert matrix fuel, should be investigated, and I think, implemented.

[The prepared statement of Mr. Todreas follows:]

PREPARED STATEMENT OF NEIL E. TODREAS, EMERITUS PROFESSOR OF NUCLEAR SCIENCE AND ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA

Good morning, Chairman Bingaman and Ranking Member Domenici. My name is Neil Todreas and I am a Professor of Nuclear Science and Engineering (emeritus) at the Massachusetts Institute of Technology.

It is an honor to be called before you to discuss the subject of the Global Nuclear Energy Partnership, a matter of considerable importance to the future of nuclear energy. I have been asked to address the state of the technology needed for the execution of GNEP.

As an overall characterization let me be clear that DOE is only at the start of a very significant program of technical research & development, a program being conducted by a large team of dedicated and expert professionals which will require multiple decades of scientific and engineering accomplishment. Nevertheless I believe such an R&D program to evaluate the potential of nuclear energy systems operating in the closed fuel cycle is an important national undertaking. I do so for reasons of ensuring national influence in the global evolution of fuel cycle technology as well as creating closed cycle technologies (separations, fuel fabrication, transmutation and reprocessing) sufficient to demonstrate that nuclear technology can recycle its spent fuel if called upon to do so.

Regarding the first reason as I've noted previously<sup>1</sup>, "There are basically three costs of the U.S. not supporting separation technology going forward. First, and most importantly, we will lack the technical knowledge to be credible and influential in the evolution of commercial nuclear power. Second, we will not acquire the knowledge necessary to develop effective safeguards for operating reprocessing facilities in other nations. Third, we will not acquire the knowledge to permit us to make timely and informed judgments about long-term options for closed nuclear fuel cycles that may be of importance in future generations." These costs dictate that we pursue such R&D. The second reason is that enlarging the options for spent fuel

<sup>1</sup>My testimony of April 6, 2008 before the Subcommittee on Energy, Committee on Science, United States House of Representatives.

management is a prudent step in the expected scenario of increasing nuclear power deployment.

Regarding GNEP technologies let me start with the three facilities needed to demonstrate the key technologies:

1. A Consolidated Fuel Treatment Center (CFTC), which will conduct LWR spent nuclear fuel separations( and later commercial reprocessing of burner reactor transmutation fuel.)
2. A prototype Advanced Burner Reactor (ABR) that will demonstrate transmutation of actinides and fast reactor technology.
3. An Advanced Fuel Cycle Facility (AFCF) to develop the reprocessing and fabrication technologies needed for test transmutation fuels and eventual recycling of ABR cores using Transmutation Fuel. It will provide the experience needed to design, license, and operate a commercial scale facility for recycling the ABR core's Transmutation Fuel.

A major decision for the CFTC and ABR is the appropriate scale for these facilities. The recent NAS review<sup>2</sup> makes a strong case for the initial construction of smaller engineering versus large-scale facilities for both the LWR spent fuel separation facility and the burner reactor (a 100—200 MT/yr separation facility and a 50 to 100 MWe advanced burner test reactor are suggested). Additional reasons I would add to this case are the need for caution in the scaleup from bench-scale separations success and the need for a flexible and dedicated irradiation test bed for transition fuel development and qualification.

Underlying the determination of readiness to proceed with even such engineering scale demonstrations is the assessment of the readiness of the technologies to be used. Hence I now turn to the technologies being developed and evaluated for operations and design of these facilities.

- Separations of LWR spent fuel in the CFTC—Several approaches are being considered. UREX+ which has been under development for some years in our national laboratories, principally ANL and two commercially controlled processes COEX and NUEX. Each of these processes meet the GNEP Statement of Principles that pure plutonium will not be separated, although importantly the Principles do not reference the required chemical or isotopic diluents which must be combined with the separated plutonium. The COEX and NUEX processes would produce a mixed Uranium (U) and Plutonium (Pu) oxide product (exact proportions likely differ between processes) suitable for thermal reactor recycling. The UREX+ suite includes a series of processes which extract various actinides and fission products in groups or individually (processes +1 through +4). These UREX processes can yield transuranics (TRU<sup>3</sup>) material for fabrication into transmutation fuel for irradiation in fast reactors or inert matrix fuel for transmutation in a thermal reactor. Transmutation of TRU material in fast reactors as well as thermal reactors is discussed later under the ABR heading.

The key GNEP requirements for these separation processes are being developed as Criteria, e.g. total process losses of radiotoxic actinides from separations and fabrication activities of 0.2%; specific separations efficiencies for U, minor actinides<sup>4</sup> and key fission products; and a scalable process meeting international safeguards norms (facility metric tonnage per year capacity has not been yet set—total national capacity needed could be about 2000 MT/yr of LWR spent fuel whereas existing international facilities are about 800MT/yr ) as well as General Goals, e.g. limited emissions and high-level liquid waste production fuel cycle costs causing no more than a 10% increase in LWR busbar cost of electricity; repository acceptable waste forms; and a licensable facility.

Key among these requirements are the efficiency of separation and the associated degree of acceptable losses of actinides and fission products to waste streams, losses which must be controlled to avoid burdening rather than assisting spent fuel waste management. A major output of the solicitation of commercial interest now underway is to learn what industry believes is feasible regarding such specific requirements.

The DOE selected reference technology is UREX +1a ( its separated products are U, Technetium, Cesium/Strontium, TRU and all other fission products). As of summer 2007 it had only been demonstrated at bench-scale over short times

<sup>2</sup>Review of DOE's Nuclear Energy Research & Development Program, National Research Council, Released October 29, 2007.

<sup>3</sup>Plutonium (Pu),Neptunium (Np),Americium (Am) and Curium (Cu).

<sup>4</sup>Neptunium (Np),Americium (Am) and Curium (Cu).

with fresh solvents. Hence variations in process chemistry over the long term have not been established.

- Fabrication and Demonstration of Transmutation Fuel for the ABR—the ABR will most likely be started with traditional sodium fast reactor driver fuel, not fuel with transuranic isotopes (TRU). As the core loadings undergo recycling, and since multi-recyclings are required to effectively transmute the plutonium and minor actinides,<sup>5</sup> fuel elements with TRU content are required. These are called transmutation fuels and require a significant fabrication and long irradiation testing program. A significant fabrication program is needed because large-scale remote fabrication consistent with hot-cell operations must be developed. Further, for oxide fuels the effect of Americium (Am) due to its high vapor pressure on the fabrication process is unknown as is the effect of lanthanide fission products on the fuel's required oxygen-to-metal atomic ratio and irradiated materials properties, both of which impact achievable fuel pin performance. For the alternative metal fuel, large-scale fabrication without loss of Am due to its volatility must be developed and again the effect of lanthanides but here on potential fuel cladding chemical interactions must be resolved.<sup>6</sup>

A long period of development is needed because the fuel elements must be irradiation tested in a fast neutron reactor of which none exists in the US and only a few are available worldwide. First technical feasibility is to be established by fuel pellet fabrication and irradiation of short pellet stacks in a simulated fast neutron environment in the thermal Advanced Test Reactor (ATR) in cadmium shrouded test positions. This work has been underway for several years. Next, engineering feasibility will be established by irradiating long length pins in the fast reactor environment. Activities to initiate this phase are also ongoing. Finally fuel qualification will be achieved by producing a fuel pin and fuel assembly product that are suitable for licensing.

For the transition of the ABR core load to Transmutation Fuel, lead test assemblies (LTAs) are contemplated for insertion in the ABR. As successful irradiation experience is gained the ABR core will be gradually loaded with recycled transmutation fuel. However, this concept of demonstrating satisfactory LTA operation in a commercial reactor as well as the gradual transition in that reactor core to a full transmutation fuel loading runs counter to the prevailing fuel performance approach in our commercial fleet. Specifically, the US LWR commercial industry is adopting a goal of zero fuel failures by 2010. It is likely that commercial acceptance for operations of a core load of Transmutation Fuel will require prior demonstration of failure-free operation of multiple core loads of identical fuel in a non-commercial facility. These factors dictate that qualification of transmutation fuel for ABR performance will be a long and costly process—longer than the 10 year period currently envisioned. The GNEP program properly has Computation and Simulation as a major research ingredient. It is my hope and expectation that the transmutation fuel development and demonstration will be increasingly impacted by such simulation capability, a capability which could decrease the time and cost of in-reactor irradiations by development of sufficiently accurate models of fuel behavior under irradiation and their exercise by faster-than-real-time computation.

- The Design and Construction of the ABR—The GNEP ABR is envisioned as a sodium-cooled fast reactor, commercially designed, constructed and operated. The choice of sodium coolant is plausible based on a balancing of its inherent characteristics and the extensive, although not uneventful, worldwide operating experience of the late 20th century. Further, the benefits of coordination with existing sodium reactor programs of all major nuclear development countries favor the choice of sodium over alternative concepts whose development is far less advanced. Nevertheless, an evaluation of competing reactor technologies using a systematic set of selection criteria as pointed out in the NAS report would be most desirable.

<sup>5</sup> Various, although not particularly attractive options exist for minor actinide management other than irradiation of a homogeneous mixture with plutonium in fast reactors eg. storage (of Curium), target elements, and a minor actinide-only fueled reactor due to the special characteristics of the principal minor actinides Americium, Neptunium, and Curium.

<sup>6</sup> Frank Goldner, USDOE, "GNEP Transmutation Fuel Development," Presentation to the 2007 Regulatory Information Conference, March 15, 2007 as quoted in the NAS study cited in footnote 2.

For any type fast reactor selected for GNEP, and especially for the sodium option, two principal challenges for technology development are the generation of a design of sufficient.

1. safety characteristics as well as the development of a risk-based, technology neutral framework for pursuing its licensing and
2. a capital and operating cost profile such that it can gain commercial acceptance.

The DOE has properly engaged industry to address these sodium reactor design strategies. Important systems engineering studies underway are also addressing what the performance requirements of these reactors should be, chief among them the value of the core conversion ratio which impacts the number of fast reactors and processing facilities needed. System studies should also evaluate the proposal below for a thermal recycle program component which was raised in my 2006 testimony and in a minority view of the NAS study.

It is obvious that deployment of fast reactors in numbers sufficient to make a meaningful transmutation contribution is far in the future. Our operating LWR fleet is a ready resource in which to conduct thermal neutron transmutation on a schedule dictated by development and qualification of suitable fuel materials. In the inert matrix fuel option, a portion of the core is loaded with inert matrix fuel composed of TRU and inert material, thereby eliminating the U238 isotope which would if present transmute to Pu239, a material we set out to transmute and thus eliminate in the first instance. Inert fuel development, although already extensively studied internationally, has challenges, key among them the reprocessing of diluent material, which will require considerable further work although likely less than that needed for fast reactor transmutation fuel. This two-tiered fuel cycle option of first thermal reactor transmutation followed by reprocessing and then fast reactor transmutation of the resulting vastly limited quantity of TRU should be evaluated for the GNEP program. This strategy has the potential to accelerate the start of transmutation of TRU material and also reduce the number of fast reactors needed for the ultimate disposition of TRU from the LWR fleet's spent nuclear fuel.

- Grid Appropriate Reactors—GNEP proposes small-scale reactors for developing economies for which fresh fuel would be provided and spent fuel returned to the supplier states. GNEP also designates these as “proliferation-resistant international modular reactors” (PRIMR). As I noted in 2006, “The small scale is not necessitated by the fuel cycle but rather the electrical grid and capital structure of the developing economy. Such a supply and spent fuel return arrangement would provide adequate proliferation safeguards in an era of worldwide expansion of nuclear technology. It is, however, by no means certain that the capital and fuel cycle costs of these small-scale reactors would yield an attractive cost of electricity (COE) for these economies. Considerable R&D needs to be supported by DOE to refine such designs to a level where realistic COE can be projected and proliferation-resistant effectiveness assessed, especially if fast spectrum design options are to be considered. There are, however, some innovative LWR designs already existing and pebble bed reactors being developed in South Africa and China that offer considerable advances in reactor safety features which bode well for introduction of nuclear power into technically unsophisticated nuclear economies, if competitive COE can be achieved.” The laboratory proposal is for a dual-path approach for PRIMR development and demonstration. A fast-track deployment of a near-term reactor to gain US leadership in the rapidly emerging global nuclear market in support of GNEP objectives and a second path of specific technology development and demonstrations needed to deploy second generation PRIMR concepts. A suitable number of concepts exist for the first path. The development targets for the second path must yet be established. This will be done through an assessment of user country needs and constraints in concert with the international community leading to the development of a set of PRIMR system requirements.

In conclusion the development of technology needed for GNEP is a large and technically demanding task. Significant activity is underway which is facing and working through the resolution of multiple technical challenges. No insurmountable barriers exist to my knowledge although my recent exposure to these extensive development programs has been limited by the inactivity of the Nuclear Energy Research Advisory Committee and consequently its key oversight activity in this area, the Advanced Nuclear Transformation Technology Subcommittee. The scale, ownership, timing, and ultimate cost of the principal GNEP facilities are key strategic questions. Their answer depends on many factors—among them very importantly the continued progress and results of this development program.

## APPENDIX A.—SOURCES CONSULTED

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3. P. Lisowski, GNEP Presentation to Nuclear Energy Research Advisory Committee (NERAC), February 20, 2007.
4. J. Rempe et al., Status Report to NERAC. Advanced Nuclear Transformation Technology Subcommittee of the Nuclear Energy Research Advisory Committee, February 21, 2007.
5. F. Goldner, USDOE, "GNEP Transmutation Fuel Development," Presentation to the 2007 Regulatory Information Conference, March 15, 2007.
6. Report of Advanced Nuclear Transformation Technology Subcommittee of the Nuclear Energy Research Advisory Committee, April 2, 2007.
7. Fast Reactor Technology. Chris Grandy, Manager, Engineering Development and Application Department, Nuclear Engineering Division; Presentation to GAO, May 24, 2007.
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15. J. J. Laidler, Technology Options for Spent Fuel Recycling. International Symposium: Rethinking the Fuel Cycle. MIT, Center for Advanced Nuclear Energy Systems, Cambridge, Mass., Oct. 30-31, 2007.
16. D. Stout, Director, Office of Light Water Reactor Spent Fuel Separations Recycling Used Nuclear Fuel (CFTC Project), November 7, 2007.

The CHAIRMAN. Thank you very much.

Senator Dorgan wants to make a statement at this point.

**STATEMENT OF HON. BYRON L. DORGAN, U.S. SENATOR FROM NORTH DAKOTA**

Senator DORGAN. Mr. Chairman, before we go to the final witness, I have to be at Senator Reid's office, the Majority Leader's office for a meeting, and I don't have the opportunity to get out of that at the moment.

But I did just want to say that Senator Domenici and I are the Chair and ranking member on the Appropriations side on these issues, and I really appreciate you calling this hearing on the authorizing committee, No. 1. No. 2, I think the statements have been really interesting and fascinating and add to the body of knowledge here, so I just wanted to thank the witnesses, and I apologize, I have to leave early, but I've had a chance to review the statements and will have the opportunity with Senator Domenici and others on the Appropriations Committee to use this information, as well.

Mr. Chairman, thank you.

The CHAIRMAN. Senator Domenici.

Senator DOMENICI. Before you leave, Senator Dorgan, might I say publicly, as ranking member of the subcommittee that you

chair, a committee that I have been, effectively, chairman of for maybe 25 years, because when Senator Reid was there, he frequently let me chair, even when he was in charge. I enjoyed that committee immensely, and now I enjoy it with you.

It is burdened with the biggest problems it's ever had, with the adequacy of budget funds for the maintenance of our National Laboratories, which is rather startling to both you and I. Your meeting with the leader wouldn't have anything to do with how we might solve that problem?

[Laughter.]

Senator DORGAN. It does not.

Senator DOMENICI. Why don't we set one up and see if we could get one? Thank you very much.

The CHAIRMAN. All right, Mr. Seshadri, go right ahead, we're glad to have you here.

**STATEMENT OF PATTABI SESHADRI, PARTNER AND MANAGING DIRECTOR, BOSTON CONSULTING GROUP, BOSTON, MA**

Mr. SESHADRI. Mr. Chairman and members of the committee, I appreciate this opportunity to testify today on the findings from our study on nuclear fuel recycling economics.

First, I will briefly highlight the unique elements of our approach, and I'll discuss the summary of findings of the study. I will then conclude with the risk management benefits of portfolio solution, comprising a repository recycling combination.

We believe there are five—a few unique aspects that differentiate our approach. First, the Study brings an industrial perspective to recycling, starting with a specific cost economics based on actual capital and operating expedience at existing AREVA facilities at La Hague and Melox.

Second, we took an independent view in analyzing the estimates provided by AREVA.

Third, we gathered and put on key assumptions from a variety of sources external to AREVA and this is important in the sense that we included interactions with senior managers at four of the top ten U.S. nuclear utilities as part of the study.

Fourth, this is a fairly important point, because some of the recycling economics comes down to utilization. Our study recognizes that the size of accumulated spent fuel, and new annual spent fuel discharge in the U.S. market, and provide the basis for a world-scale recycling plant, operating at high levels of utilization and we have presumed an 80 percent utilization of these recycling facilities.

This can help achieve advantaged economics. Just as world-scale LNG petrochemical, refining and other industrial facilities achieve cost advantages relative to their smaller, less well-positioned competitors.

Finally, our study considers criteria beyond economics that can provide significant risk management benefits, which I'll highlight.

We compared the economics of recycling in repository strategies in two different ways. Today, I'll just focus on the second version of the comparison, which was comparing the economics of a recy-

clung repository portfolio solution, versus a pure once-through strategy that will require an additional repository in the future.

The recycling repository portfolio solution has an estimated net present cost of \$48 to \$53 billion. It is based on a new, integrated recycling plant, opening in the year 2020, in addition to the development of a repository. In comparison, an exclusive once-through strategy with the development of multiple repositories over time, has an estimated net present cost of \$47 to \$50 billion. This represents, in our mind, a \$1 to \$2 billion difference in baseline estimates between net present costs between the two alternatives.

We estimated the sensitivity of the conclusions to various factors, such as capital costs of the facilities, the price of uranium, discount rates, and the like. The impact of uncertainty in each of these variables is of the order to zero to 14 percent of the estimated baseline net present cost. This would translate to the potential of approximately \$7 billion in variation net present costs between a portfolio solution, and a pure once-through solution.

Given the uncertainties of the cost projections, both on the repository and the recycling facilities, we determined that the baseline difference of \$1 to \$2 billion is indeed, the economics of the two facilities are comparable.

In addition to the comparable economics that are very important risk management benefits that we considered. First, developing a world-scale recycling facility has the potential to eliminate the need for additional repository capacity beyond the initial 84,000-ton capacity until the year 2070.

Second, the recycling repository portfolio solution can contribute to early reduction of used fuel inventories at reactor sites by removing newer, hotter fuel for recycling within 3 years of discharge.

Third, the recycling repository portfolio solution relies on existing technology with known improvements. Such an incremental approach, we believe, can reduce the implementation risks substantially, and provide an operational transition to future development, technology developments. In this regard, we would view this as a retro-version of a 1975 Chevy, but with all of the added amenities that you can add through technological improvements over the last 20 years.

Finally, recycling offers a tool for utility nuclear fuel buyers to protect against future increases in uranium prices. The recycling solution can produce annual nuclear fuel supplies of 20 to 25 percent of the U.S. nuclear fuel needs, increasing supply security which is a significant factor as you look at the economics of nuclear power.

In conclusion, our evaluation of nuclear fuel recycling indicates that the economics of recycling repository portfolio solution are comparable to a once-through or repository-only solution. In addition, recycling repository portfolio solution can provide very important risk management benefits, warranting further consideration of recycling in the United States.

I would be pleased to answer any questions you may have at this time.

[The prepared statement of Mr. Seshadri follows:]



PREPARED STATEMENT OF PATTABI SESHADRI, PARTNER AND MANAGING DIRECTOR,  
BOSTON CONSULTING GROUP, BOSTON, MA

Mr. Chairman and members of the Committee: My name is Pattabi Seshadri, and I am a Partner and Managing Director with the Boston Consulting Group and Leader of BCG's Americas Utility Practice. I appreciate this opportunity to testify before you today on the findings from our study on nuclear fuel recycling economics which was completed in July 2006.

The Boston Consulting Group is a Global Management Consulting firm with over 6,000 employees across 60+ countries. BCG advises corporations in every major market and industry sector, as well as prominent public sector organizations. A majority of our clients in the Americas, Asia Pacific and Europe rank among the largest corporations in those markets. In addition, BCG also consults to and advises non-profit and governmental organizations. The firm conducts strategic and economic analyses and supports implementation of major improvement programs at clients across a number of sectors including, energy, industrial goods, technology and communications, financial services, health care, and consumer products. BCG's energy practice comprises a significant proportion of our global activities.

What I plan to present today is a summary of the findings from The Boston Consulting Group's study of the economics of recycling and once-through fuel cycles. First I would like to begin by discussing the unique characteristics of our approach that differentiates this study from other such economic assessments. Then I will discuss the summary findings of our study including the key sensitivities in the results. I will then highlight the risk management benefits—beyond economics—that we believe a portfolio solution comprising a repository/recycling combination can deliver. Finally, I will conclude with a few directional observations around recent market changes that have further affected the balance between recycling and repository economics.

#### OUR APPROACH

There have been many studies to date that have focused on the economics of recycling relative to repository solutions. However, we believe there are five major themes that differentiate our overall approach to evaluating recycling economics which we would like to highlight prior to discussing the study findings.

First and foremost, this study brings an industrial perspective to recycling, starting with specific cost economics based on actual capital and operating experience at existing AREVA facilities. In this regard, our study benefited from an "open-book" approach, in which AREVA provided us proprietary operating and accounting data from its operations at La Hague and Melox. In addition, we were provided unfettered access to a variety of AREVA's internal technical and economic experts in each relevant area of operation. We should note that this project was not meant to be an accounting audit of the data provided by AREVA to test its veracity. However, the level of access provided by AREVA helped us in gaining confidence in the underlying assumptions of the study and in maintaining a high level of analytical rigor.

Second, we took an independent third party view in analyzing the estimates provided by AREVA, using our expertise in industrial cost analysis to validate assumptions. In many cases, we developed specific methodologies to triangulate on sensitive data elements or explain cost differences with previously reported data. For example, AREVA provided a bottom-up build up of recycling facility costs taking into account specific facilities that will be required, high value process improvements that can be implemented, and the unique characteristics of the U.S. market in terms of licensing, security, engineering and construction standards and requirements. In this case, we conducted a top down validation of the cost of the recycling plant which represents a significant portion of the overall cost. We estimated this just as we would typically assess the cost of an industrial project which involves introducing a state-of-the-art technology in a new market—taking into account local conditions, feasible range of cost improvements from operating experience, and the like.

Third, in addition to accessing AREVA information we also gathered input and feedback on key assumptions from a variety of sources external to the company. We conducted informal interviews with experts in academia, in the Department of Energy's National Laboratories, and in the energy industry. Specifically, we undertook a substantial effort to involve key senior managers at four of the top 10 U.S. nuclear utilities as they are important stakeholders with regard to spent fuel management issues. Our effort included three separate steps—at the beginning of the project we solicited input on the key issues from their perspective; we then conducted an interim dialog on findings to understand and address potential areas of concern; towards the end, we presented our final findings in a workshop setting.

Fourth, our study is unique in that it explicitly recognizes the differences in the US market relative to other international markets where recycling has been implemented. The US market has the largest base of legacy spent civilian nuclear fuel to be addressed—approximately 55,000 metric tons accumulating across utility nuclear plant sites across the nation. In the case of some of this legacy fuel, it would not be advisable to directly recycle all of it, as the recycling by-products would have adverse radioactive characteristics. However, some of this accumulated base can be recycled in dilution with more recently discharged spent fuel—providing a steady source of spent fuel for a large scale recycling facility. In addition, the US nuclear market also has a large installed base of nuclear plants annually generating approximately 1,900 to 2,100 metric tons of spent nuclear fuel on a consistent basis. Taken together, these two sources provide the basis for a ‘world scale’ recycling plant that can operate at very high levels of utilization on a continuous basis—unlike any other facility in operation today. This can indeed help achieve more advantaged economics—just as ‘world scale’ Liquefied Natural Gas (LNG), petrochemical, refining, cement and other industrial facilities achieve cost advantages relative to their smaller, less wellpositioned competitors.

And finally, our study considers important elements beyond economics, such as the impact of recycling on flows of used fuel, the improved ability to optimize repository space in a recycling-repository ‘portfolio’ solution, and the potential risk management benefits of such an approach. It is our view that these are important financial and other benefits of recycling that are not fully reflected in ‘straight-up’ economic comparisons.

We would like to note that throughout this engagement, BCG had complete control over the emerging results, key messages, and analytical comparisons. Under BCG’s agreement with AREVA, the company may only publish this report in the public domain without any further alterations. Any changes or alterations by AREVA would need to be specifically agreed to by BCG.

#### FINDINGS ON RECYCLING ECONOMICS

We developed economic comparisons of recycling and once-through repository strategies using two analytical approaches. The first is a theoretical comparison of the estimated long-term cost of recycling used fuel and the estimated cost of a repository to handle the same used fuel in a once-through strategy. This comparison is referred to as the “Greenfield” approach. In the Greenfield approach, no consideration was given to existing legacy fuel stored at the utility sites. The key economic metric is the unit cost, expressed in dollars per kilogram (\$/kg). The Greenfield approach answers the question, “How much would it cost to recycle used fuel in the U.S. over the long-term?” In this respect, the Greenfield approach lends itself well to comparisons with previous studies that have used a somewhat similar approach.

The second approach involves comparison of recycling as a solution that would complement development of the Yucca Mountain repository, termed the “Portfolio” strategy, and a pure once-through strategy that will require additional repository capacity in the future. This second approach is referred to as the “Implementation” approach. The Implementation approach addresses economic questions such as, “How much would it cost to implement a recycling plant in conjunction with the repository?” and “What is the cost differential between a portfolio strategy and a once-through strategy in which only repositories are developed?” In this approach, we also looked at a broader set of assessment criteria. In addition to the economics, the Implementation approach addresses issues related to flows of used fuel, financing requirements and risk management.

In the Greenfield approach, we estimated the overall discounted cost of recycling used fuel to be in the order of \$520/kg. The cost of a once-through strategy using a repository was estimated at about \$500/kg. Considering uncertainties that surround many of the variables used in the assessment, such as uranium price, repository costs, recycling facility capital requirements, and the like, we determined the economics of the two approaches to be comparable.

In the Implementation approach, the cost of a portfolio strategy, based on a new integrated recycling plant opening in 2020 and handling 2,500 tons/year, combined with development of a repository (such as Yucca Mountain) for high-level waste from recycling and untreated legacy fuel, has a total net present cost of \$48-53B. The net present cost of an exclusive once-through strategy with Yucca Mountain and an additional repository is estimated at \$47-50B. This represents a \$1-2B difference in baseline estimates of net present costs of the two alternatives.

As part of our economic assessment, we estimated the sensitivity of the conclusions to various factors, including, the capital and operating costs of the repository and recycling facility, the price of uranium, discount rates used to estimate net

present costs of future cash outlays, and the like. The impact of each of these variables, with all other variables remaining constant, is of the order of 0-14% of the estimated baseline net present costs of each fuel management strategy. This translates to the potential for approximately \$0-7B in variation in net present costs of a portfolio solution that combines a recycling facility with a repository and a pure once-through solution that includes multiple repositories over time.

The largest uncertainty underlying this economic comparison is the total installed capital and operating costs—both for the recycling facility and for the repository. Given the intrinsic uncertainties of the cost projections for both of these facilities, we determined the \$1-2B difference in baseline estimates of net present costs of the two alternatives to be comparable. Furthermore, even at the upper end of the potential net present cost difference of 14% between a recycling-repository solution and a repository-only solution, we believe there are significant risk management benefits to the portfolio solution that make it worthy of further consideration. I will discuss these risk management benefits subsequently in this testimony.

It is important to note that the total undiscounted life cycle cost for the recycling strategy is estimated to be about \$113B, compared to about \$124-130B for the once-through strategy in which a larger portion of the cost is deferred. Therefore, discount rates (or financing costs) used to calculate the net present costs would differentially affect the economics of the two solutions. We assumed a similar discount rate for both the solutions in order to enable a pure economic comparison of the alternatives. As part of this study, we did not explore alternate business models such as public-private partnerships to implementing a recycling solution. While such alternatives are likely to incur higher financing costs, they would also provide financial benefits in the form of transfer of some risks to nongovernmental entities. We believe that such a cost versus risk trade-off across business model alternatives should be valued separately from the basic cost economics of the two fuel management solutions.

A key differentiating element in our assessment of recycling costs, when compared to previous studies is that the Integrated Recycling facility unit costs are significantly lower than previously published data. We estimated a unit cost for the integrated plant of \$630/kg, based on a plant with the following main characteristics:

- 2,500 tons per year of net capacity, based on effective throughput at 300 days per year (about 80 percent of nameplate capacity)
- Total capital investment (CapEx) of about \$16B, which is mainly composed of overnight cost of construction at market price, contingencies, development, licensing and start-up costs; storage costs for High Level Waste from Recycling (HLW-R) and used MOX fuel assemblies are also included and decommissioning costs are considered after the closure of the plant; and
- Operating costs (OpEx) of about \$900M per year, which include operating expenses for both treatment and fuel fabrication, running investments, estimated taxes or taxes equivalent, and other charges.

As discussed before, AREVA provided to BCG a bottom-up estimate of the capital and operating costs of a new Greenfield plant in the U.S. market. We undertook a process of reconciling these bottom-up estimates with the actual costs of recycling at existing AREVA Plants.

Overall, the total capital investment required for the integrated plant is within 10 percent of the total capital investment that has been made over the years for the AREVA European plants at La Hague and Melox. We took in to consideration some key modifications that will be required between the existing plants and the U.S. plant, including:

- A few workshops not in use anymore or not in the scope of a U.S. plant.
- No duplication of similar workshops—the La Hague and Melox facilities were built “piecemeal” over time resulting in some inefficiency (La Hague for example is made of two largely independent units).
- U.S. plant larger in size to accommodate a higher volume of used fuel.
- Limited optimization for some key process steps, based on AREVA operational experience at La Hague.
- Additional costs and contingencies, such as costs driven by specific licensing and design requirements in the U.S., development costs, etc.

It is important to note that there are inter-linked impacts that are difficult to clearly separate and quantify in this reconciliation process. As an example, when a sub-process within a plant is scaled up by 50-100% of its current size, there can be significant associated benefits around how the new process is implemented and optimized. In that instance, the cost of increasing the size of the process and the

offsetting value of scale benefits and process improvements cannot be fully and clearly separated out—only the net total benefits can be clearly identified.

Based on these assessments, we concluded that the capital investments and the operational expenses of the U.S. plant can be comparable to those of existing European plants. A key difference, however, is that a much higher used fuel throughput is expected in the U.S. plant, because of its larger size and the higher expected utilization. Utilization is expected to be at about 80 percent of the nameplate capacity, significantly higher than the current value at La Hague. Higher utilization in the U.S. is guaranteed by larger volume of newly discharged fuel and existing inventory. Thus, our recycling unit cost estimates, especially for treatment, are significantly lower than the historic unit cost incurred at La Hague and Melox.

#### ADDITIONAL RISK MANAGEMENT BENEFITS OF RECYCLING

As mentioned before, our study looked at the risk management and other peripheral benefits of a portfolio solution that combines recycling and repository approaches. While several of these features cannot directly be ‘priced’ in as part of the economic comparison, the benefits can be compelling and need to be considered in the overall evaluation. Our study concluded that in addition to comparable economics, recycling as part of a portfolio strategy presents at least four important benefits.

First and foremost, developing a ‘world scale’ recycling facility has the potential to eliminate the need for additional repository capacity beyond the initial 83,800 ton capacity at Yucca Mountain, until the 2070 timeframe. In a repository-only approach, we estimated that an extension of Yucca Mountain capacity to its estimated technical capability of 120,000 tons would be required to dispose of fuel discharged after 2020 and an entirely new repository would be required for used fuel discharged after 2040.

Second, a recycling-repository portfolio solution can contribute to early reduction of used fuel inventories at reactor sites—in particular, removing newer, hotter fuel for recycling within three years of discharge and eliminating the need for additional investments in interim storage capacity at power plant sites.

Third, the portfolio solution relies on existing technology with known improvements and modifications to enhance its effectiveness. This would be very similar to new nuclear power plant development where electric utilities migrate to subsequent generations of technologies over time rather than starting by scaling up one-of-a-kind technologies. Thus, a portfolio approach has the potential to significantly reduce implementation risks. It can also provide an operational transition to future technology developments such as Advanced Fuel Cycles and fast reactors.

Finally, a very important benefit of recycling is that it offers a tool for the nuclear power sector to protect against potential increase in uranium prices. Therecycling approach produces MOX and recycled UOX fuel to nuclear power plants. We estimate that a recycling facility processing 2,500 tons/year of spent fuel would produce MOX and recycled UOX fuel equivalent to approximately 20-25% of the US nuclear power plant annual fuel requirements. The production cost of this fuel is, for the most part, independent of uranium prices and enrichment costs. In addition, the facility would be located within the US, thus providing supply security for a portion of US nuclear fuel needs.

We believe that access to such a supply source of recycled fuel can be quite valuable. Spot Uranium prices over the last two years have averaged approximately \$75/lb compared to the 2000-2005 average of approximately \$14/lb. This included a peak price of approximately \$135/lb in 2007. The planned build out of new nuclear plants over the next 10–15 years has the potential to put further upward pressure on Uranium prices. The natural gas sector provides a useful analogy to consider the impact of such commodity price uncertainties. Between 1990 and 2005 the US power sector added approximately 250,000 MW of new gas-fired generation. During that same timeframe, natural gas prices moved up from an average of \$1.60/MMBtu to \$8.70/MMBtu, a more than fivefold increase in nominal terms. A steady and meaningful source of recycled nuclear fuel can provide a potential hedge against such price increases.

#### CONCLUSION

In conclusion, our in-depth evaluation of nuclear fuel recycling indicates that the economics are comparable to a once-through or repository-only solution. In addition, a portfolio solution that implements a recycling facility complementary with a repository development can provide important risk management benefits for the United States.

A few recent trends also appear to be improving the relative economics and comparability of recycling to a repository solution. Specifically, increasing Uranium

prices, the potential for increased future nuclear fuel demand from a nascent nuclear renaissance in the US power sector, and increasing cost estimates for a large scale repository indicate that a recycling solution can provide significant benefits in managing the spent fuel disposal problem.

Mr. Chairman and members of the Committee, I appreciate having this opportunity to join you today. I would be pleased to answer any questions you may have at this time.

The CHAIRMAN. Thank you very much.

Thank you all for your testimony. Let me start, and we'll just do 5-minute rounds, here.

First, Secretary Spurgeon, let me ask you—as I hear about GNEP, it seems to be quite a few different things under one title. One is this international partnership to advance the use of nuclear energy, and clearly that's something which I support, trying to move toward more safe use—of nuclear energy.

But there are also a lot of other things in it. I notice in the National Academy report, although Dr. Wallace, I think you had a euphemism for saying that they had a “cautious” approach to the program, in fact their statement was pretty clear. It said, “The GNEP program's goals are to develop and deploy recycling technologies that do not separate plutonium in advanced reactors that consume transuranic elements from recycled fuel. The GNEP program should not go forward, it should be replaced by a less aggressive research program. The domestic, waste management security and fuel supply needs are not adequate to justify commercial-scale reprocessing facilities, and there is no economic justification to proceed.”

That's a pretty strong statement. I know you've given us the letter that Secretary Bodman wrote in response, maybe you could elaborate on that, and explain why you think there is strong or economic justification to proceed.

Mr. SPURGEON. To the best of my knowledge, none of the efforts that went into that report were directed toward the economic justification. I take that as an opinion expressed by folks, that was not backed up by any facts within the report itself.

I believe, that in their report—and they did acknowledge this in their press release and in their briefings of the report—they were not speaking of the international effort. What they were focused on in their comment relative to GNEP not proceeding, was the R&D effort to go to commercial-scale of advanced technology, and I think that's a key differentiation.

They made the assumption that we had already selected UREX-plus technology—which as has been said here—and I would agree with—by other members on this panel—is not ready for commercial-scale deployment. But they were not addressing the idea that we as a Department have a responsibility for long-term R&D, to look over the horizon, to develop the kind of technologies, methods, systems, modeling, simulation, that will be needed to improve our nuclear technology in the future.

But we also have a responsibility to help pursue and help commercialize existing technology, which is, for example, what we do with our Nuclear Power 2010 program, and implementation of the Energy Policy Act of 2005.

So, it's two different things. They're recommending that advanced technology not go forward at a commercial scale, that it

needs to be done at engineering scale, in a normal course of development. I agree with that.

But it doesn't reflect the ability for there to be more near-term methods that could be used today.

The CHAIRMAN. I guess where I'm not understanding is, as I understand it, the Department of Energy has announced grants of \$60 million over 2 years to have industry come up with conceptual design of both this consolidated fuel treatment center, and the advanced burner reactor, to burn the transuranics from the spent fuel. Now, is it your impression that they would agree with that? That this is an appropriate thing for us to be going forward with designing and constructing?

Mr. SPURGEON. No. Designing—we have not made any commitment, nor have we requested any funds to construct, at this point in time, any facilities. What we are doing now is getting input from industry, and the international community on a technology path forward. We want the technology that we pursue to be informed by what industry tells us is needed for them to be able to proceed forward with constructing facilities, and their recommendation as to the scale of those facilities.

The definition of commercial scale varies depending on the technology that we talk about. The need for proceeding through incremental steps, is dependent on the technology that we are going to implement, and how advanced, or what kind of a step forward it is taking. If you're doing just as we're doing with Nuclear Power 2010, where we are going to Generation 3-plus reactors from the Generation-3 reactors that are in existence in the United States today, they go directly to "commercial scale." That means a fairly large reactor.

If you're talking a fast reactor that is in a much earlier stage of development, then the step that you would take in between is a smaller step. You don't go to a very large reactor. But, in a fast reactor system, commercial scale could be much smaller than commercial scale for a light water reactor.

The answer to your question is, I think, in fact the National Academy did recommend—somewhat gratuitously, since we already had these contracts in place—but they recommended that we get more input from industry, they recommended we get more input from the international community. This was already underway, but not finalized at the time they cutoff their study in July of this year, so we're doing exactly what they asked to be done. Before we proceed forward, and go into final design or construction of anything, we get input so that the R&D program is well-informed.

While I did not like the language that they used, because I think it was more headline-grabbing than anything else, the basis underneath much of what they were recommending are things that we agree with, if put in the correct context.

Advanced technology needs a step-wise approach. If you're talking about incremental improvements to technology that has been proven at commercial scale, that can allow a more aggressive approach, but in no case are we advocating that the U.S. Government proceed to—nor have we asked in the 2008 budget submission that you now have before you—any funds for constructing, or going to

final design. All we're doing is conceptual design, so that we can inform the future R&D program.

We want the R&D to be directed toward answering the questions that industry and our international partners—because we have several bilateral technology development agreements—determine are the key questions and that allow us to move forward. That is why you do conceptual design, so that you're not just doing R&D for R&D's sake, it's focused on answering the proper questions.

The CHAIRMAN. My time is up.

Senator Domenici.

Senator DOMENICI. Mr. Chairman, panelists and fellow Senators, let me say I'm very sorry that after my questions I have to leave, but I do really think this is an excellent meeting and forum, and it's exactly the kind of thing that I love about being in the Senate, and that I'll miss immensely when I'm not here.

It's also very interesting to see how you disagree so violently, yet you are great scientists who are supposed to know. One would think that if you're a great scientist, what you all would know about this would be the same, but it doesn't seem so.

We have one witness here saying, "We can proceed, and they know how," I think that witness says that, that's the last witness at the table, "because they're doing it in Europe." You don't like it, some of you don't, and American leaders seem to take an instant position that they're not in favor of the PUREX technology that's being used by AREVA and Japan—Japan's pretty cautious about taking care of waste, and they're doing it with PUREX formulation.

It seems to me when this Senator travels, wherever I travel, I'm beginning to be known as being pro-nuke, and I'm very proud as I leave the Senate that I'm given some credit with moving this ahead in America, and when America moves ahead and comes up from a deep sleep—like Rip Van Winkle in this area—it takes a lot of time to catch up. We still don't have assurance that Congress wants to do everything necessary to catch up, but we've got just about everything we need.

Except we all get asked the very same question, and that is, "Oh, yes, that's all working and we read about it, but what are you going to do about the waste?" That's all we get, you know, they're not asking what they used to about Three Mile Island. They know that now, they read the literature. Nobody got hurt at Three-Mile Island and they're past that stage. They don't ask about the Russian reactor, they understand that was not the same kind of thing. All it is, "What are you going to do with the waste?"

Let me tell you, my answer is that this country has great scientists, and great technocrats and great engineers, and we're going to find a solution, just like Europeans found a solution, and now the Japanese, of late.

What's wrong with my answer? When I answer my constituents that way? Do some of you find fault with the answer that I make when they ask me? I do not say, "We're going to use Yucca Mountain," I guess you got that. I don't tell that to the good constituents. Because I've come to the conclusion that we're not going to get there for a long time, and I also have come to the conclusion, that I'm not sure that we're going to put spent fuel rods, with all of the

energy that is contained within them, underground in the mold that's prescribed at Yucca.

I'm also not convinced that when the country knows that Yucca Mountain won't service our country in total, it will only do in part the country won't seek another solution. I heard one of the witnesses say with the legislative cap that's on it and some of the other restraints, it won't hold but about one-fourth of the need—if so, we need to build three more Yuccas, right?

So, my answer is not, "We're going to Yucca." My answer is, "We're going to find a way."

Now, I'm interested in this hearing because I thought you all were going to tell us how we could do it. I want to say one other thing. We have been used to being afraid of new technology such as the PUREX formulation. Our objection seems to be that it produces plutonium in the mainstream, and therefore it is dangerous regarding the spread of that for the making of bombs.

But you know, the countries in Europe aren't afraid of that, they're producing it, and they're taking care of it, and they're running it back through. Japan has just recently built one, and they're not afraid of it. So, I don't know why we should automatically be so frightened. On the other hand, if we could find a technology that is not PUREX-driven, that would satisfy me immensely, I would be very happy.

But, I want to come to you, Mr. Spurgeon, and I bothered all of you with my speech and didn't ask you a question yet. But I want to say to you, Mr. Spurgeon, I remember when you got sworn in, when you came before us and wanted this job, and you still look and talk like you did that day. That's really refreshing to me.

I think you have done a terrific job. You're enthused, you're trying to do the right thing, you're unabashed, your mission seems to me to be one that you believe in, and I commend you for it. We're getting somewhere.

I want to say to the rest of you—when America started back like it was coming back, and renaissance was the word used, and I happened to go to Europe for a speech on what was happening in America, I want to tell you, all of the European countries, even those that are way ahead of us—France, for one—they were all thrilled that the United States of America was coming back to the party from a deep sleep. You know, we can't say we're half awake, we've got to open both eyes, and we've got to come out of the sleep.

In my opinion, if you all can help us by telling us how we can get from here to a recycled facility as soon as practicable, and how it would be done, then I would say that what you have to offer is something that we are glad to have; but we ought to make sure we've got enough technology and scientists who say we can do it, and how, and we ought to proceed.

So, Mr. Spurgeon, I am suggesting that, I don't know that this international approach is the first step, it may be in its infancy, the first step, but I'm wondering if you would comment on what I'm thinking about—does the Department think it's not possible to do what I'm thinking about here, and expressing?

Mr. SPURGEON. No, sir, you're not off-base at all, relative to our ability to put together—if there is that kind of joint cooperation between the Congress and the Administration, and I think there can



be—to put together a structure to manage used fuel in a business-like way, looking to the future.

Now, I'd be glad to answer that, but I would tell you, I'm going off the reservation a bit—and this is me talking, and I'm not speaking at this juncture, if you'll allow me, for Administration policy. I know when I speak that is the Administration, but I have to, if I can, come off of that just a little bit.

Senator DOMENICI. Go ahead.

Mr. SPURGEON. Because we can consolidate and I think we should consolidate management of the entire back end of the nuclear fuel cycle. I think it should be done in a way which would allow ordinary business decisions to be made, and it can be done in a way that does not require Federal funding.

Because we are collecting from our utilities today, one mil per kilowatt hour, we have on deposit some \$20 billion in the nuclear waste fund, and that's increasing by about \$750 million per year. But we do not have access to that money. It can not be used to effectively, and reliably manage the government's responsibility to take spent nuclear fuel from our country's nuclear reactors.

Senator DOMENICI. It sits there and adds to the Federal Government's assets, so it reduces the deficit of the United States every year, and the debt. But every time you try to use it, it runs into the notion that you aren't using it for Yucca. That, you know, that's the problem, and here we sit not intending to proceed with any rapidity with Yucca. We have \$20 billion and growing, and we have to do the same kind of things Yucca was supposed to do. We're trying to do it another way, but we're stuck.

So, we have to address that and you're right.

Mr. SPURGEON. I think if we address that kind of an issue and create the kind of structure that we have created before, for other purposes—

Senator DOMENICI. Yes.

Mr. SPURGEON [continuing]. Senator Corker knows one of them, because it's located in his area, a kind of government entity that can operate with a revolving fund, can pay its own way, and can be able to manage—whether it be interim storage, whether it be recycle, whether it be a geologic disposal—in the way that most effectively is required for the management of that resource. That's how you go forward with the building of these facilities.

Research and development is the province of the government, research and development is the province of the Department of Energy. We need to look over the horizon, we need to develop the technologies that are going to be required for us to take the next step into the future. To go into simulation and modeling, to be able to reduce the cost of future plants, to be able to find ways in which we can create, in effect, designer molecules that can be able to truly provide us with alternative separations technologies that can go into the future—that's where our National Laboratory and our universities excel.

Where we excel from a business standpoint, where we excel from an industry standpoint is in actually implementing those technologies. To be able to do that in a business-like way, to have access to some sort of a revolving fund, you need access to the receipts that are coming in each year to the nuclear waste fund,

without funding being driven by the annual appropriation-process. These are ways which I think could help enormously, relative to how we go forward in the future to manage this program that needs a long-term perspective.

Senator DOMENICI. Senator Bingaman, some of our people will stay and ask some additional questions, but if you will, I have to leave.

The CHAIRMAN. All right.

Senator DOMENICI. Could I say thanks to Dr. Wallace, and say I hope your mother's well and you at least, as a member of the scientific community of Los Alamos, you were at least smiling.

[Laughter.]

Senator DOMENICI. Maybe you feel comfortable in this environment, and back home it's not that way, but we'll all be coming up to see Los Alamos people and make sure that we talk to them about what's going on.

I want to say it's very nice to have the Harvard and the MIT sitting side by side.

[Laughter.]

Senator DOMENICI. Having such different opinions. It sounds very good that you do, I won't tell you which side I come down on, but obviously what I have said would seem to indicate where I am—

Mr. BUNN. I think our opinions may be less different than you think, and that I also, like Neil, support a strong nuclear R&D program, and want to see it go in a step-by-step fashion.

Senator DOMENICI. Thank you, Senator Bingaman.

The CHAIRMAN. All right, thank you.

Senator Craig.

#### **STATEMENT OF HON. LARRY E. CRAIG, U.S. SENATOR FROM IDAHO**

Senator CRAIG. Mr. Chairman, thank you very much. Let me make a few brief comments, and then ask probably just one question. I want to play off both what you as the Chairman, and the ranking member have spoken to this morning, and my question will be directed at you, Dennis.

I am not in disagreement with reprocessing, if we have the skill and the talent to do it, and we do. I'm also pleased to hear you suggest that it is not the Federal Government's role, it is the private sector's role, creating the right structures within the Federal system because of the nexus we've always had historically, dealing with this energy forum.

What I do believe is important is finding a path forward that does two things. Which pushes the R&D, which we do well—you've spoken to that—and that's where we ought to be focused, Mr. Chairman, when it comes to the resources that we can generate, as we bounce off from, spring off from, leap off from EPAC, and what appears to be—nuclear renaissance that's occurring out there.

There is no question that out there, into the future, there is going to be substantial need both for fuel, and the management of the waste. We've not found a clear path forward to do that.

It's been fraught with politics a good deal more than it has science, but that's reality. A lot of us are struggling with that, try-

ing to deal with it, both for commercial purposes, and for defense purposes.

But having said all of that, everyone sitting on this dais right now has within their States, laboratories, so we're very interested in what they'll be doing, and what roles they'll be playing in all of this.

At the same time, we have the technologies that were spoken to by the last speaker, and the ability to nudge those a little forward. I am simply one of those that would suggest, it's not the Federal Government's role to do that. It may be the Federal Government's role to facilitate and help get that done, by the way we control the processes, as it relates to nuclear fuels and generation.

Our role is R&D and I'm glad to hear you speak to that, because I think that's tremendously important, with the limited resources that we have available. As much as we will push in the future to get more budget, for these purposes, to advance that, to spring into new reactor concepts like NGNP, that operate at high-temperatures and therefore produce processed heat—there is already a rapidly growing industry out there.

A group of industry interests that need processed heat, recognizing Mr. Chairman, that if we do climate change, and we're 20 years out from new technology on coal, that we're going to see a lot of energy switching or fuel switching going on, if you cap and control, and that's going to be natural gas, and then we want hydrogen cars, and that's going to be natural gas. So, government ought to be right out on the edge of pushing new technologies, in that respect.

With that, and recognizing the time allotted, Mr. Secretary—GNEP is operating a \$120 million Fiscal Year 2008 budget, if we are not able to get you any more money, how do you plan to prioritize GNEP's spending under that scenario?

Mr. SPURGEON. It will be prioritized, basically as we have prioritized Fiscal Year 2007. We are operating in Fiscal Year 2007 at the \$176 million rate—it is an R&D program. We are prioritizing, looking at what areas of research and development are needed to break down the roadblocks to the ultimate commercialization of advanced technology. We're looking at getting input—continuing input—because we have a program in place now to get input from industry via the work from the four consortia that have been selected.

We want to continue that effort, to get industry input on the technology roadmap, to get the industry input on the economics, the business case for how we should proceed. But, it is a technology development program, that's what it will be, obviously at the rate of \$120 million, the progress will be slower, there's no question about that.

Senator CRAIG. So, in what I've just heard from you, how much of that will actually go into R&D versus reconnaissance? Of the money that will be spent in Fiscal Year 2008, \$120 million, how much of that will go into outreach—I call that renaissance—versus actual R&D at the laboratories?

Mr. SPURGEON. The majority of it is actual R&D, if you're talking renaissance, do you mean the industry efforts?

Senator CRAIG. The outreach that you are currently under to find your path forward, or to define it more clearly, as I read it, versus advanced fuel cycle and all the kinds of things that are currently underway that might lend to that path forward?

Mr. SPURGEON. You're probably looking at—and this is coming totally off the top of my head, I'll give you a detailed answer for the record.

Senator CRAIG. Sure.

[The information previously referred to follows:]

If the GNEP appropriation is \$120 million, we expect that around \$20 million will be used to support the four industry teams that were awarded cooperative agreements in September 2007 to conduct conceptual design studies, develop technology roadmaps, and develop business and communications plans to build an advanced nuclear recycling facility and advanced recycling reactor. Input from the industry teams will help inform a Secretary of Energy decision in 2008 on the path forward for GNEP. The remainder of the appropriated funds would support research and technology development into advanced fuel cycles by national laboratories and universities, in collaboration with international partners where appropriate.

Mr. SPURGEON. But you're, talking about in excess of 75 percent, 75–80 percent is straight R&D, in terms of money that we spend. The vast majority of our money is spent at our laboratories and universities, from the standpoint of R&D expenditures.

We are doing work with industry, we think that's important to continue, but it informs the R&D program. Without that, we're kind of like a rudderless ship—we need to have direction, so that what we're spending is effectively spent, and well-directed.

Senator CRAIG. OK.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Corker.

#### **STATEMENT OF HON. BOB CORKER, U.S. SENATOR FROM TENNESSEE**

Senator CORKER. Thank you, Mr. Chairman, I want to thank the panel, obviously a very intelligent, informed group, and with a lot of differing opinions.

But, I'd like to begin by asking the Secretary, you know the—stating and then asking—you know, as we deal with potentially being involved in carbon issues, and then we look at nuclear and just—it continues to dismay me, the lack of coherence, if you will, in trying to clear a pathways for us to do things that cause our country to be more energy secure in a way that actually everybody can embrace.

But stepping away from that, just looking at recycling for a second, from the standpoint of us fully embracing the full potential of nuclear energy in our country, how urgent is the issue of finding a solution on the storage/recycling piece?

Mr. SPURGEON. I think it's very urgent, because there's no question that spent fuel can be stored, first in pools, then in dry casks, it's perfectly safe, it's being done now, I don't disagree or dispute any of that. What we're doing today is safe.

But, we don't need just the 30 or so plants that are now in the pipeline for potential license applications, we've had three to date, and we're looking at perhaps having a half a dozen before the end of year, maybe 20 by the end of next year.

We need something like 300 new plants if by the middle of this century, we're going to make a dent in any kind of CO<sub>2</sub> avoidance regime.

When you start talking about needing that kind of an expansion of nuclear power, and it is doable, then you run into the two questions, and Senator Domenici alluded to them earlier—two questions we've always had with nuclear power—is it safe? What are you going to do with the waste?

When you then start talking about that kind of an expansion, you've got to have a durable, credible, solution to "What are you going to do with the waste?" I happen to believe that the way you deal with high-level waste is this—a chunk of vitrified glass that is the product of a recycling facility.

This high-level waste is robust, yet is durable. It can be placed in a variety of geologic media safely.

The other thing we've got to do is simplify the waste management challenge. Right now if you dispose of spent fuel, you're looking at some 300,000 years before it would get to the level of radiotoxicity of natural uranium. If you look at where we are existing technology-wise, you might be down to somewhere in the 9,000-year range, based on existing—or similar to—existing technology, not necessarily exactly what we have today. Anybody will tell you, this curve depends on things like, the burn up of the fuel, and how long after it's discharged, it's reprocessed—but that's a rough approximation as to where we are today, but that is significant. Because we have demonstrated licensability in this range.

What we're trying to get, ultimately with GNEP—is down to this level, where we might be talking about just hundreds of years before the waste is to the level of toxicity of natural uranium.

What that does is simplify the problem—we have to make the disposition of nuclear waste easier, so we have more options to manage it. It needs to be managed in the most appropriate way to the individual constituents of the nuclear waste. You can't do that when you just take one big lump, put it in a great big steel cask and stick it underground—that is a solution, it is workable, but it's not what we want to get to, if we want to expand nuclear energy the way it needs to be expanded worldwide.

Senator CORKER. When you say "urgent" how many years does it mean in terms of having a commercial solution? Does GNEP, the efforts with GNEP, take away from our ability to do that more quickly here in our country? Because I'm running out of time here, and still want answers—

Mr. SPURGEON. Sorry.

Senator CORKER [continuing]. What is it—no, no, it was a great answer—what is it that you guys do agree on? In other words, we've heard a lot of differing testimony today, what is it you do agree on? The two or three things that everybody at this table would say, "Yes, yes, yes."

Mr. SPURGEON. I'm going to guess here, because Dr. Bunn may not agree on this one, but I hope if I go to the point of saying, the ultimate need to close the nuclear fuel cycle, we could all—

Mr. BUNN. Nope.

Mr. SPURGEON. Can't even agree to that.

The problem is, when people say, "I don't think you need to close the fuel cycle, I think you can just store it safely, dry cask storage," then you come up to the issue that arises when you say, "Well, wait a minute, that's not a permanent solution, that's not a solution to the nuclear waste issue, we can't just leave it lying around on the ground," and therefore that comes back to people who want to oppose new nuclear plants, or a large number of nuclear plants, saying, "You haven't solved the waste problem, therefore you shouldn't build any more nuclear plants." We've gone through this circle, I've seen this move too many times, because I started in this business 40 years ago. Where we've gone around to, "How are we going to deal with the nuclear waste?" It was Lions, Kansas, we're going to vitrify it, put it in salt, and that's going to be the permanent solution.

Then we came to, "No, we're just going to interim store it," that was the Waste Policy Act of 1977. "But that's not a permanent solution," so we changed that in the Energy Policy Act of 1982, now it's going to go permanent disposition of spent fuel, because at that point, nuclear energy was going in the toilet.

So, then we come to 1987, it's still storage, interim storage, then "long-term" storage, then permanent storage plus retrievability. That drives you to a rock repository which is the, the hardest of all criteria—it has to be permanent, yet it has to be retrievable.

Now we say, "Wait a minute. We need those energy resources, we need a lot of nuclear power, we need a more durable solution, therefore, we're going to need to recycle that fuel, we're going to need to use the resource value that's contained in it, and we're going to then create a better forum to be disposed of," that gives us—for future repositories—other alternatives that we didn't have when the Waste Policy Act was passed in the 1980s.

Mr. BUNN. It seems to me, that the future of nuclear power will be best assured by making it as simple, as cheap, as safe, and as proliferation-resistant as possible, and that using the technologies of reprocessing, and recycling that we have available in the near term, points in the wrong direction on every one of those counts.

It's precisely because I, too, believe that we need a growing nuclear power enterprise that I am so opposed to moving forward with the technologies that we have today. I think everyone on this panel, No. 1, would agree that nuclear energy is probably going to have to be a major part of the answer to climate change. No. 2, would agree that we need a strong nuclear research and development program.

I think—and I would absolutely agree that if we get to the point where we have closed fuel cycle technologies, it will be cheaper, safer, and more proliferation-resistant than once-through that we should use those technologies. I'm not opposed to closing the fuel cycle on principle, I'm opposed to solutions that are more expensive, more risky, and more proliferation-prone than the other solutions.

So I think there's actually—the only key disagreement is whether to rush now to build commercial-scale facilities, or whether that doesn't make sense while we move forward with more advanced technologies that might have more promise for the longer term.

Mr. SESHADRI. Senator Corker, if I may add one clarification—try a point of agreement here, which would be that the uncertainty and the cost of both types of facilities is something that, I believe, everybody in this panel would agree to, again, that's probably a logical extension of what I think and I've seen, in the sense that you cannot pin down the cost of any of these types of facilities.

In an industrial setting when we face those types of issues, we advise our clients to get the information that they need in order to close down the certainty. In that regard, one example would be to at least explore the possibility of a commercial scale recycling facility in a conceptual design stage, to get that additional piece of information that'll help you resolve some that uncertainty.

The CHAIRMAN. Why don't we go on to—

Senator CORKER. I filibustered—

The CHAIRMAN. No, you didn't—

Senator CORKER [continuing]. As good as I can, and—

The CHAIRMAN. No, you did fine.

Senator Wyden, and then Senator Sessions after him.

#### **STATEMENT OF HON. RON WYDEN, U.S. SENATOR FROM OREGON**

Senator WYDEN. Mr. Spurgeon, there is a big gap between what you say, and what the National Academy of Sciences says. The National Academy of Sciences was unanimous in saying that your program shouldn't go forward, that it can't be justified on any of the reasons, not a one, that the Department has put forward. Not economic reasons, not technical reasons, not the threat of nuclear proliferation with respect to the amount of waste that needs to be managed, you all get a goose egg from the National Academy of Sciences.

Now, my question to you is—were you aware—I'm looking at all their publications, they put out press releases and reports—I'm looking at one publication and it says, and I quote here, "All committee members agree that the GNEP program should not go forward." All of them. Were you aware of that, and just decided you'd proceed anyway?

Mr. SPURGEON. I was very much aware of that when they issued their report, which was a week or so old at that point in time, but I think, Senator, you need to put that in context as to what they meant. They were very clear—

Senator WYDEN. Oh, I am very—

Mr. SPURGEON [continuing]. In their brief they were very clear—

Senator WYDEN. Sir, sir, they're very clear, and that's why I'd like an answer to the question. They said all committee members agree that it shouldn't go forward, what's your response to what they said?

Mr. SPURGEON. They said we should close the nuclear fuel cycle, but we should not take advanced technology that has not been proven and proceed directly to commercialization of that technology.

They also made clear that their comment was not pertaining to the international program of GNEP, which is what we're pursuing with the 17 countries that have signed the GNEP Statement of

Principles, and the other 18 countries that are observers to that program.

That includes many aspects of GNEP that they are agreeing with—the small reactor program, the reliable fuel supply program—GNEP is a broad program, it is not just an R&D effort. The R&D portion of GNEP is the advanced fuel cycle initiative, that the same committee said should go forward—the R&D should go forward. They were disagreeing with taking the advanced technology and taking it directly to commercialization.

In discussion with them, they agreed that there were technologies that could be commercialized directly today, without going through the engineering scale.

Senator WYDEN. Mr. Chairman, I would just hope that we could hear from the National Academy of Sciences directly, because I think Mr. Spurgeon wants to parse this and that. It says all committee members agree that the GNEP program—not this part or that part—should not go forward.

Let me ask you about one other thing that concerns me again, out of the recommendations from the National Academy. You all go forward with this program that the National Academy is quite critical of, but you cut funding for the University Nuclear Research and Education programs to zero. Not a penny. Not for last year, not for this year. What is the rationale behind that?

Mr. SPURGEON. Sir, we are spending more money in Fiscal Year 2007 on university programs than we spent in 2006. If our budget is approved for 2007, as it is submitted to the Congress, we will be spending even more money at universities for programs. You're speaking of a line item that is one part of the money that we spend at our colleges and universities. We are going up in spending.

As these programs, research and development programs expand, our universities are very integral parts to their execution, and we certainly recognize that, they've made great contributions to our R&D efforts, and we would anticipate that they would in the future.

**Funding Table**  
(Dollars in Thousands)

NE University Programs	FY 2006 Actual *	FY 2007 Actual	FY 2008 Request **
University Reactor Infrastructure and Education Assistance	26,730	16,547	\$0
Research Reactor Infrastructure	\$0	\$0	2,947
<b>R&amp;D Program Funded Research</b>	<b>24,391</b>	<b>38,711</b>	<b>58,572</b>
<i>Generation IV</i>	6,067	6,274	5,772
<i>Nuclear Hydrogen Initiative</i>	5,116	4,300	4,300
<i>Advanced Fuel Cycle Initiative</i>	13,208	28,137	48,500
<b>Total Funding for Universities</b>	<b>51,121</b>	<b>55,258</b>	<b>61,519</b>

\*The 2006 actual does not include National Laboratory directed funding for universities.

\*\*Total funding for Universities is expected to be as shown subject to appropriations in out year.



Senator WYDEN. This money again—I'm looking at your materials—zeroed it out for 2007, 2008, it goes to universities like Oregon, you know, Oregon State—the Congress, of course, is trying to add it back in. The point of this is—and I know my time is about to expire.

You know, what's going to happen as a result of your efforts is we're going to see an effort to put more waste up at Hanford. They can't deal with all the waste that is being put there, you know, today. I just hope, particularly after we hear from the National Academy of Sciences, Mr. Chairman, and I hope that we can work out an arrangement, I know time is, you know, very tight to find additional opportunities for discussions with the session winding down, we can change the priorities of Mr. Spurgeon's office, because I think it's bad news for Hanford, I think it's bad news for the country, I think it flies directly in the face of what objective observers are saying, and I hope that we'll be in a position to take another look, and I thank you for the time.

The CHAIRMAN. Senator Sessions.

**STATEMENT OF HON. JEFF SESSIONS, U.S. SENATOR  
FROM ALABAMA**

Senator SESSIONS. Thank you, Mr. Chairman. This is a good hearing, because nuclear energy is an important part of our future. In my own mind, I would say that there are a number of goals that we should have for our energy policy in America. National security—we need to be less dependent on foreign oil. We need to reduce pollution that NO<sub>x</sub>, SO<sub>x</sub>, particulates, and so forth.

We must have affordable energy. I do not believe that this Congress should be a part of an effort that, the end result is a significant increase in the cost of energy to consumers. That's certainly not a good policy, and we have to remember that, and we also want to do what we can and should to reduce CO<sub>2</sub>, and to work on that, so I think nuclear power meets all of those. I would say it meets all of those goals that we should have as part of our energy policy, and I think we've got to go forward with it.

Now, Dr. Orszag said we're talking about a very large cost—\$5 billion per plant to go on this reprocessing route. I guess Secretary Spurgeon—who would pay for this process? Is this going to be a cost attached to the nuclear power industry? Is it a cost that the taxpayers would pay? How would we connect any costs for future reprocessing?

Mr. SPURGEON. Sir, if we manage this as a system, speaking broadly, of the overall system and structure for managing spent nuclear fuel, and we do it in a business-like way—we will do it in the least costly way that allows the job to be done. I don't think anyone is advocating—including myself, who I would call a strong advocate of recycling—that we do something that is going to create a burden on the consumer.

But we do have to do things that will allow nuclear power to move forward and achieve its promise. It's expensive to try and open up—

Senator SESSIONS. I guess my question is—with regard to a reprocessing facility and the cost that might be incurred there, would it be like the storage system today, that the nuclear power compa-

nies are sending money to the government to store their waste, and the government is not storing their waste, and they're still having to send billions of dollars forward. Are they going to be the ones to pay for this? Or this will be a taxpayer-funded project? Or have you thought that through?

Mr. SPURGEON. Certainly, sir, I hope that we don't end up with the same situation we have with the Nuclear Waste Fund, where it goes in and is used to offset the deficit, or to offset—or to pay for other governmental programs that have nothing to do with taking care of the spent fuel. If we can create a system where we have access to those kind of moneys to manage the whole back-end of the nuclear fuel cycle, and we can do it on a business-like basis—the answer is, then the utilities will get something for their money which, right now, as you point out, they're not. What we're doing is, been getting sued by utilities. If, you know, we're looking at a potential \$7 billion liability by the time Yucca Mountain is scheduled to open in 2017.

Senator SESSIONS. How many billion dollars?

Mr. SPURGEON. Seven.

Senator SESSIONS. All of this goes toward the feasibility of nuclear power.

I visited a plant in Alabama just a few weeks ago, because it's on the Chattahoochee River that's so dry that we're afraid that it may not have enough water flow to keep it operating. I was told the entire Southeast, Southern Company system, that this facility results in the lowest power in the entire system, cost. So, if they were shutting down plants based on economics, it would be the last one.

Do any of you doubt that nuclear power—even with the disposal of waste—should be competitive in the next decade in actual cost to the consumer?

Mr. TODREAS. You mean, will be competitive. It certainly will be competitive. Perhaps—probably—the lowest cost.

Senator SESSIONS. This is—

Mr. BUNN. Existing plants will almost certainly be the lowest cost, because once the capital is paid, the operations costs for nuclear are quite small. New plants are still going to struggle to be competitive with—it depends in part on gas prices, and what kinds of carbon taxes come in for coal, and things of that kind.

Senator SESSIONS. The coal factor is also important with regard to how clean we want the coal to be, but even at current technology, it would be competitive, assuming some increase in the price of coal, which is probably inevitable, would any of you disagree with that?

Mr. TODREAS. Very, very close, and probably competitive.

Senator SESSIONS. Because coal has substantial pollutants, and carbon emissions that nuclear power does not have.

My time is up, Mr. Chairman, thank you for hearing this. I just believe we've got to work through these problems, I'm not sure what the answer is, precisely. I'm glad, I guess, Secretary Spurgeon, you're not opposing an immediate move into recycling, but you believe it's a direction we must go, is that the way you would say it?

Mr. SPURGEON. Yes, sir, I believe that the marketplace will determine the right time to move into that, and with that, the industry's willingness to proceed forward on an economic basis, to be able to process the fuel, and through that processing, create enough of a reduction in the avoided cost for future repositories, to make it a economically viable circumstance.

The CHAIRMAN. Thank you.

Let me just ask, Dr. Todreas, you've heard Secretary Spurgeon's explanation of how he interprets the National Academy's report, and what they disagree with in GNEP. Are you in agreement with him on that? Is that what the National Academy has problems with? The taking of current technologies to full scale commercialization? That's what I understood him to say that—

Mr. SPURGEON. You're taking advanced technologies that have not been demonstrated beyond the lab, and taking that to commercialization, the National Academy disagreed with.

The CHAIRMAN. Is that your view of what, the sum and substance of what they disagree with?

Mr. TODREAS. Yeah, if I answer your question relative to the sum and substance, I think that is the point. I think the Academy's report, though, is clear if you read on, in terms of their backing of a vigorous R&D program on the closed cycle, to develop the technologies.

The CHAIRMAN. OK.

Mr. Bunn, do you have any issue with that characterization of what the Academy has concluded?

Mr. BUNN. I think the Academy does, panel did support a strong nuclear R&D program on—not only the closed cycle technologies—but on other technologies. They emphasized that the highest priority should be given to the Nuclear 2010 Program, which as I understand, Assistant Secretary Spurgeon agrees with, completely.

I would differ a little bit in his characterization—it seemed clear to me that they were not only against building commercial scale facilities with technologies that hadn't been demonstrated, but they made the point that there was no economic justification for rushing now to build commercial scale facilities, period, even with technologies that we know.

The technologies we know, after all, are technologies that we also are quite familiar with, they are high-cost and high-proliferation liabilities. If you look to the market for your information, what you find is that the British plant will close soon, because it can't get any more contracts from utilities, that the French and Russian plants are both operating at well below capacity, because of the limited ability to get contracts from utilities, and that the Japanese plant was so expensive that the utilities successfully demanded a multi-billion dollar bail out from the government in the form of a wires charge that will make electricity for all consumers more expensive in Japan for decades to come.

When utilities have a choice, they don't choose to reprocess. I was, therefore, pleased to hear Assistant Secretary Spurgeon say that we'll let the marketplace determine. I think if the marketplace determines, we're not going to be building commercial scale facilities for a long time to come.

I should say, by the way, there's, I think no hope whatever that we're going to be able to keep it to one mil per kilowatt hour if it's going to end up being the Nuclear Waste Fund that finances these operations. I think it's absurd to think that we're going to be able to reprocess, recycle, build fast reactors, et cetera, for a net cost for the utility of one mil per kilowatt hour.

The CHAIRMAN. Dr. Todreas, did you want to add something?

Mr. TODREAS. Yes, let me just make a footnote, relative to this point that came up on university funding.

It's clear that the Department of Energy has funded universities toward GNEP technologies. But what they've done is they've taken the base university program which covers more fundamental and broader aspects, and pulled that into GNEP. What the controversy is on is zeroing that out, not that the fact that the universities aren't being funded to do program-directed things. The university program for balanced development needs a bit of both. That's the issue.

The CHAIRMAN. All right.

Dr. Spurgeon, is the Department of Energy considering establishing a government corporation to carry out GNEP activities?

Mr. SPURGEON. There are a number of alternatives being considered, as possible ways to accomplish that objective. Basically talking to you on my own behalf, if you will, it is one of the structures one can look at that might be able to do that in a way that is self-funded, and not requiring annual appropriation based on the unified management of the back-end of the fuel cycle. So, it is something that has been given some thought, amongst other things.

The CHAIRMAN. All right.

Senator Craig, did you have additional questions?

Senator CRAIG. I just wanted to close out the discussion that I think is important about the National Academy of Sciences priorities. Many of you have reacted to those priorities, and I think generally we all agree their reaction to the commercialization of GNEP technology that wasn't proven. The potential costs involved.

You know, 2010 near-term reactor, yes, that was first on their list, second NGNP, Generation-4 or NGNP 2020, now, we talk about. Universities were clearly a part of their concern, and last, INL infrastructure.

Any of you want to discuss that any more broadly, as it relates to this future that we're trying to move ourselves into?

Doctor.

Mr. TODREAS. Yes, I would just go back to the INL infrastructure, I think Secretary Spurgeon's predecessors, when they designated and set up and focused on INL to have one, dominant, civilian national lab for development, I think that's a step in the right direction. But to make that work, and sustained, really requires activity and focus and funding as the Academy pointed out.

I've been a member of NERAC—we covered that issue, made reports, made recommendations in that regard. We've got to hire the best people there, we've got to retain them. We've got to give them the superior facilities, and that effort long-term, independent program, has to be maintained, and maintained successfully. I hope that NERAC, as it gets reconstituted and reinvigorated will get back and focus on that.

Senator CRAIG. Anyone else wish to make comment on those additional priorities that the Academy spoke to?

Mr. SPURGEON. Be happy to. Those priorities, I agree with. The issue is, yes, we have to do more for infrastructure in Idaho, we've talked about this many times, to a degree, if this is our laboratory, I'm embarrassed a little bit at some of the state of some of the facilities, they need to be improved.

There also needs to be emphasis on NGNP, there also needs to be emphasis on 2010. But, what we really come down to is, what is the priority of nuclear energy? Are we just talking about taking a very small pie, and trying to argue over what the slices of that pie are? How do we get the pie bigger?

Because what is needed is a priority on our overall allocation of resources, and I happen to believe that it's not by our arguing with our friends over in the renewables area to say, "You ought to take it from solar and put it in nuclear, you ought to take it from geothermal, you ought to take it from this," I think what we're really looking at is if energy is going to be one of our national priorities, we need to look at its proper level of overall funding, not to try and say, "Let's take from Peter to give to Paul." We need to look at the overall emphasis that we place on energy supply, as part of our national budget. In doing that, I think we can get away from some of this, which gets into, "Well, gee, is GNEP taking away from a university program, or is 2010 taking away from NGNP?" Those kind of arguments, I don't think are constructive.

What we need to be focused on is the importance of all of these programs moving ahead, because we're looking at needing to rely on nuclear energy to play a much broader role in our Nation's energy future.

We're now 70 percent of the non-emitting sources of power. So, if we're looking at increasing electric generation by 50 percent between now and 2030, that means we need a lot more nuclear power, that means we need a lot more emphasis on this area, as a whole, not just in one piece of it.

Senator CRAIG. Let me get to Dr. Bunn, then—but before I move to him, let me say, yes, I agree. But under the current model, the pie is small. The pie won't get larger, based on our budget constraints, unless DOE gets out of the box it's in and starts partnering with industry and getting the resource that's out there and ready to be invested in advanced technologies, that is, a private-Federal partnership that we've never been into before, we just don't think well that way. It is a new day, and we ought to think much differently then we do.

Then we won't have to worry about CBO or OMB sitting there, with their green eye shades on, crunching numbers that may or may not exist. For the frustration of this Chairman and this person who sits on both authorizing and funding, suggesting that we want to push the pie larger, and we'll take it out of solar, and we'll take it out of wind, and I agree with you, Mr. Secretary, we lose when we do that.

Right now, and for the next 25 or 30 years, the technology you speak so eloquently of, is the clean technology that we ought to be dealing with.

Doctor.

Mr. BUNN. I think what Assistant Secretary Spurgeon just said is probably another point that, if I had to guess, I would guess everybody on the panel agrees with—the need for a larger overall energy R&D investment in our country.

I just wanted to make a plug for two particular technologies that are both within the GNEP umbrella currently, that I mentioned in my testimony.

One is the quite small, potentially factory-built reactors that are sometimes called nuclear batteries that might be shipped to a particular site, and generate power for 10 or 20 years, and then be shipped back. I think that has great potential for providing energy in the developing world, and great potential for doing so at low proliferation risk. The issue at the moment is, can you do it at a reasonable cost? That's going to take some R&D to find an answer to that question.

Second, we—for many years—have not been investing what we need in the safeguards technologies of the future, including—as I'm sure you would say—working with commercial industry to integrate some of the kinds of technologies that are already being implemented in other areas, in the commercial world. There is real-time tracking of inventory that goes on at Wal-Mart's factories and warehouses that doesn't go on for nuclear material today, and we need to change that. So, there's a need for a real reinvestment in the technology of advanced safeguards.

Mr. SPURGEON. We found two areas to agree on.

[Laughter.]

Senator CRAIG. Mr. Chairman, that's an advance.

Thank you.

The CHAIRMAN. All right.

Senator Corker, did you have additional questions?

Senator CORKER. I guess I'm still confused about the urgency, then, because I look at 6 people who tremendously advocate nuclear energy and advancements in that way. I hear a Secretary talking about the recycling piece being very, very urgent. I hear other intelligent people saying that, really, it's not.

So, Dr. Bunn, I'd love for you to address that.

Mr. BUNN. I think if you ask the people who are running nuclear reactors today, and you ask the people who are seeking to build nuclear reactors today, they would tell you that the thing that's urgent is for the U.S. Government to take the fuel off their hands in one way or another. Once that happens, they don't really care very much what happens to it, ultimately. At least in the near-term.

It is true that we need to be perceived by the public as having some kind of solution to nuclear waste in the longer term. I personally believe that we need to move forward in an expeditious way with Yucca Mountain. If we are perceived as succeeding in that, that will be a sufficient solution for the near-term.

As I mentioned, the recent studies suggest that the physical capacity—and I'm well aware of the legislative capacity—of Yucca Mountain is many times the legislated capacity, and would be enough for a growing nuclear energy enterprise in the United States for decades.

I should also point out that, even once we put fuel in Yucca Mountain, it is intended to remain open for a century or more, and

therefore, if we develop technology that is, in fact, cheaper, safer, more proliferation resistant than leaving it in Yucca Mountain, there's absolutely nothing preventing us from taking it out and applying that technology at that time.

So, what closes off options, what locks us into technologies, is rushing to build commercial facilities now. What leaves all options open, and can be done for a very low cost, is storing the fuel for now, and moving forward as well as we can with Yucca Mountain, which we're going to need regardless of whether we recycle or not.

Senator CORKER. I understand there may be some differences in how you store it, based on whether you plan to reuse it in the future or not, and some of those things, I guess we could talk about at another setting.

But, let me just—Senator, we're bumping up against noon, and I know a number of us have other meetings—you showed the chart about the life of 9,000 years, moving down to 300 years—what is it about GNEP that allows us to shorten that life that we cannot do on our own accord, right here in our own country, working with our own scientists? That's a piece that, I guess, I'm missing.

Mr. SPURGEON. In going from 9,000 years to 3 hundred years? Yes, we can do it, in fact, we demonstrated it at laboratory-scale. In fact, we're doing an end-to-end test associated with that right now at the Oak Ridge National Laboratory. So, can it be done? Yes.

But, as was pointed out—and I think correctly so by some of the other panelists—there's a big difference between demonstrating something in the laboratory and making it work at commercial scale. That's really the difference. So, can we do it? Are we developing it? Can we be successful? I happen to think so. But, that will take time.

What I was trying to point out is that there are intermediate steps that one can take along the way that are consistent with the ultimate GNEP goal. That do get us to a better solution than just taking spent fuel and putting it in the ground by itself.

Mr. TODREAS. If I could go to what I think the essence of your point is, it's separations. Rather than having the spent fuel together, and having to deal with all of the constituents, together and therefore being tagged with the characteristics of the most difficult—if you separate the pieces, the uranium, the actinides, the plutonium, with fission products, you can deal with them each separately, and you've got a shot at reducing times that way.

That also goes into your urgency—urgency can be, take immediate steps to do something in a physical, practical way, but it also can be seeing that if we're going to get to separations in an effective way, we have to start an R&D now, even though the results that would come out of it are 10 years down the road. That's an urgency, too. To start an R&D vigorously and pursue it consistently.

Mr. WALLACE. I would just like to add onto that, you know, we're dancing around the issue in Yucca Mountain, and as the Assistant Secretary showed—if you're trying to design the repository that will last 100 to 300,000 years, which is really driven by an actinide, neptunium, and what its breakout would be—it's a problem that has no way to do an economic analysis about how much that would cost. So, the urgency is extreme—if we're going to close the fuel

cycle, which we really, strongly believe you need to do, then you need to find a way to deal with the actinides.

As the Assistant Secretary showed you, there's a way to deal with the short-lived isotopes. Is you vitrify, we have a way to do that, it's on a time-scale, so we all can deal with. But, if you're going to leave actinides around, especially when you're talking about a huge ramp-up globally, then you have to deal with those. It's not just uranium or plutonium, it's in particular, neptunium.

Mr. SESHADRI. Senator Corker, just one other point I would make, comment I would make on an earlier point that was brought up, which is preserving optionality for the country.

If you think about an ECD solutions, a do-nothing solution is going to be the lowest-cost solution, and it's really not a solution, because you have these other issues that you need to deal with. Maybe—especially when you have such uncertainty in the cost of a repository and recycling facilities, when you think about it, it will be better if you look at both options and proceed with both options, to a point in time when you have better certainty on one or the other. Rather than committing to a technology, way up front, one or the other, way up front, and locking yourself into that. That's another way to think about the optionality. I do agree with the point that you want to preserve optionality, but there are extremes of how you can do that.

Senator CORKER. Everybody's head is shaking up and down in agreement on that point, too.

So, Mr. Chairman, I thank you for bringing in such a distinguished panel, and thank all of you for spending time.

I do want to know if the Bostonians are all riding back in a car together, or—

[Laughter.]

Mr. BUNN. Are all what?

Senator CORKER. Are you all traveling back together?

Mr. BUNN. No, I don't think so. My guess is, we're fine. I certainly flew down.

The CHAIRMAN. All right, well, thank you all very much. This has been useful testimony. I think we've gotten some good issues out here for discussion.

That will end the hearing, thank you, again.

[Whereupon, at 11:59 a.m., the hearing was adjourned.]



## APPENDIXES

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### APPENDIX I

#### Responses to Additional Questions

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##### RESPONSES OF NEIL E. TODREAS TO QUESTIONS FROM SENATOR BINGAMAN

*Question 1.* The Advanced Fuel Cycle Initiative developed a number of separations based on the Uranium Extraction Plus technology or UREX+.

a. What are the advantages of the UREX+ process as compared to simply not separating the fuel and letting it thermally cool over a number of years as outlined in the MIT study?

b. How close was the program to demonstrating the technology on a pilot scale?

c. In your estimation, how far away would such a program be from demonstrating it on a large engineering scale?

Answer. 1a. The fundamental advantage is that by separating the chemical constituents of the light water reactor spent fuel, their radioactive isotopes can be dealt with separately by various different strategies based on the basic characteristics of each isotope: for example half-life, toxicity, heat load, fission cross section.

1b and 1c. It is instructive to answer these questions by creating a listing of throughput of the various scales of operations and their potential time availability. Based on my queries and request, Dr. J. Laidler of ANL has created such a Table which I have attached. The potential availability dates of the types of operations shown in this Table, are dates which I believe represent reasonable achievable estimates.

*Question 2.* What is your opinion on using PUREX or variations on it to separate spent fuel as compared to a once through fuel cycle?

Answer. The PUREX process separates out pure plutonium. Hence, I do not believe it is desirable for the U.S. to now embark upon a course to utilize this process for initiating reprocessing of light water spent fuels. I would need to be presented with the specific technical and potential economic characteristics of the different variants of this process, to then be able to decide upon the merits of their use.

*Question 3.* Do you think industry by itself would adopt a MOX fuel cycle for the existing light water fleet?

Answer. The U.S. industry has little to no incentive to take this step by itself.

*Question 4.* What are the principal safety concerns with fast neutron reactors? Are they commercially viable?

Answer. The principal safety concerns, as well as the desirable design features, vary considerably with the various candidate reactor types—sodium, gas lead and liquid salt-cooled reactors. Let me restrict my answer to the leading candidate, the sodium cooled reactor. Its safety concerns are the control of reactivity for several well-established limiting transients, as well as the exothermic chemical reaction, should the sodium contact water or air. I believe, based on extensive design and considerable operational experience with sodium reactors worldwide, that these concerns can be effectively managed.

Based on this past construction and operating experience, it can be concluded that the capital cost of the sodium reactor is currently 1.2 to 1.5 times greater than a light water reactor. Some designers project that parity can be achieved; demonstration of such is the principal challenge for the sodium cooled reactor.

##### RESPONSES OF NEIL E. TODREAS TO QUESTIONS FROM SENATOR DOMENICI

*Question 1.* Given all the political obstacles, escalating cost estimates and finite capacity of Yucca Mountain, and the growing DOE liability for failure to take pos-

session of spent fuel, what do you think is the right U.S. waste management strategy going forward?

Answer. 1a. It is very desirable to initiate the movement of spent nuclear fuel from reactor sites to storage at a few centralized facilities or a single site. Completion of this movement need not be precipitous, but should be an objective for the next several decades. Among potential sites is Yucca Mountain, which could be operated as an interim storage facility with the spent fuel stored in an easily retrievable manner. In the longer term a repository needs to be identified and licensed. The needed repository capacity might be impacted over the long term, i.e. multiple decades, by a successful reprocessing and transmutation research program demonstrating that an effective closed cycle can be implemented. The available capacity of a repository should be maximized by effective studies and design for thermal and radiological imposed loads.

1b. It is still important to proceed with the application to the USNRC, to license Yucca Mountain since the current basis may well be suitable to support a successful application. In any event, the experience to be gained through the USNR review will be invaluable for any needed future repository application.

*Question 2.* In previous testimony on GNEP you raised concerns about the manpower necessary to support an expansion of nuclear power in the U.S. What needs to be done in this regard?

Answer. The manpower needs are at multiple levels—technicians, operators, engineers, researchers and managers—in multiple organizations—DOE, NRC, national laboratories, vendors + AEs, utilities (or operating companies) and universities. To some degree, particularly for technicians and engineers, recruitment from the general technically-educated pool, can be accomplished. However, nuclear power is a demanding, multi-disciplined technology, requiring that its technical and management leaders are well educated regarding the affect that design features and actions in every area can have on the integrated response of a reactor plant.

Consequently, it is essential that a healthy and substantial nuclear engineering university community exist in the U.S. Existence of such a community requires substantial government and industrial support to convince university administrators to sustain such departments or programs in light of the multiple other technical and scientific areas that compete for their attention. Finally, the nuclear engineering programs need experimental facilities, key among them being university research reactors to impart hands-on experience to their students.

*Question 3.* In your testimony you have come to the conclusion that the U.S. should support and R&D program to close the fuel cycle to ensure “national influence in the global evolution of fuel cycle technology as well as creating closed cycle technologies sufficient to demonstrate that nuclear technology can recycle its spent fuel.” Your colleague from Harvard, Dr. Bunn, seems to have come to the completely opposite conclusion because it would send the wrong message to the rest of the world. What message do you believe we send if the U.S. takes the leadership role in technology development, security and safeguards?

Answer. I believe it signals that the U.S. is returning as a global leader in nuclear technology and that we will be engaged from a firm technical base in global debates on suitable directions in these areas. Key among these areas are the evaluation of commercial nuclear power including options for the fuel cycle. It will further signal that we will adopt choices for U.S. direction in these areas considering, in part, international technical understanding in these areas. We will also be in a much better informed position with respect to development and enforcement of effective safeguards.

*Question 4.* You note in your testimony that GNEP is a technically daunting challenge, but “no insurmountable barriers exist.” How many countries have the capability to support a R&D program of this magnitude? Are they doing so?

Answer. I was referring to the potential to successfully achieve the GNEP technical objectives. By support, I interpret that as participation in GNEP in a technically meaningful manner; certainly France, Japan and Korea are doing so. Further steps are being taken to engage Russia, China and potentially India; I believe these are the major fuel cycle R+D contributors.

*Question 5.* You mentioned in your testimony a recycling strategy that utilizes a new type of fuel for use in existing reactors in the U.S. What are the advantages of this approach? Will this reduce the number of fast reactors you will need in the future? If uranium costs remain low, this will give us a way to extend repository capacity without fast reactors? Could this be integrated into the US recycling program in the future?

Answer. The advantage of the approach—using inert matrix type fuel in a portion of the core of light water reactors—can achieve reactor operation without net accu-

mulation of actinides, on a faster time scale than that required for the construction and qualification of fast reactors.

This approach does require a final transmutation of fuel in a fast spectrum reactor to achieve desired actinide isotopic content. However the number of fast reactors with this dual tier approach is a considerable reduction from that required for a fast reactor-only strategy.

Yes, this can be made a part of the US recycling program.

*Question 6.* Do you think we need more R&D in the area of advanced nuclear fuel cycles? What should our priorities be?

*Answer.* I do believe it is in our national interest to develop the technology for a closed fuel cycle. To do this in a timely manner requires an enhancement of the current AFCI level of research. As noted above, the thermal recycling approach should be part of this program. Elements of closed cycle research that should be pursued for both thermal and fast spectrum options are: reprocessing spent LWR fuel, fabrication of recycled fuel and design of reactors for these options. Since these steps are interrelated within each option, it is not prudent to focus exclusively on only one or two elements; rather, a program coordinating each aspect must be fashioned. It should also be kept in mind that fuel reprocessing is required to support the development of fast breeder reactors, which can utilize uranium to produce energy a factor of fifty or more times larger than a LWR-only strategy. This will eventually dispel concerns over the sustainability of nuclear as a CO<sub>2</sub>-free source of energy.

The R+D program should also include activities on the once-through fuel cycle which could yield benefits with fewer short-term risks and lower costs of development and deployment than for closed fuel cycles. Such activities would include characterization and investigation of alternative waste forms, engineered barriers and geochemical and hydrological environments for waste repositories. Additionally, alternative concepts for the repository concept itself, such as the deep borehole disposal approach, should be investigated.

COMPARISON OF OPERATIONS FOR DEVELOPMENT, VALIDATION AND DEPLOYMENT OF LWR SPENT FUEL PROCESSING METHODS BASED ON AQUEOUS SOLVENT EXTRACTION PROCESSES.

<i>Type of Operation</i>	<i>Throughput</i>	<i>Potential Availability</i>
Laboratory scale testing of aqueous separations processes for LWR spent fuel treatment	0.5–5.0 kg (heavy metal) per run; experiments repeated during the year as funding permits	Now; several DOE laboratories have the necessary facilities and equipment
Engineering-scale testing of separations process segments	0.5–1.0 tonnes (heavy metal) per year; extended duration of individual runs; used for process optimization and tests of innovative concepts	2020–2025, with the Advanced Fuel Cycle Facility; also there is the potential for use of foreign facilities (France, Marcoule; Japan, Tokai Works; U.K., Sellafield BTC)
Pilot-scale testing of separations processes (complete, fully-integrated process)	50–100 tonnes (heavy metal) per year, high capacity factor; proof-testing of industrial process and plant designs	Possible in the U.S. program by 2025; potential for collaboration with Russia in their pilot plant that will be operational in 2012–2015 time period.
Production-scale processing of LWR spent fuel	800 tonnes per year (conservative approach) to 2,500 tonnes per year (to keep up with the present generation rate in the U.S.)	2020–2025

## RESPONSES OF MATTHEW BUNN TO QUESTIONS FROM SENATOR BINGAMAN

*Question 1.* It is my understanding the Department is working with South Korea on separations technologies—do you consider this reprocessing?

Answer. The Department of Energy is working with South Korea on technologies related to pyroprocessing, or electrometallurgical treatment of spent fuel. I believe that pyroprocessing should be considered a form of reprocessing (and should therefore be considered sensitive nuclear technology under the Atomic Energy Act), in that it chemically processes spent fuel to recover a product that is predominantly (though not entirely) plutonium. Rather than focusing on whether the word “reprocessing” is the best word, however, we should focus on the proliferation risk. As I noted in my testimony, states pursuing pyroprocessing will gain experience and facilities for chemical treatment of intensely radioactive spent fuel, and in plutonium metallurgy, which would be useful in reducing the time and cost to carry out a nuclear weapons program. For those reasons, I believe we should be essentially as concerned about limiting the spread of these technologies to additional states as we are about limiting the spread of PUREX reprocessing facilities to additional states.

*Question 2.* Can you please explain why you view variations of the PUREX process as a proliferation risk?

Answer. Processes like COEX are only modest variations on the PUREX process traditionally used to separate plutonium for nuclear weapons. In essence, rather than extracting the plutonium in pure form, they extract it mixed with a portion of the uranium from the spent fuel. A state with a COEX plant would have all the experience needed to separate plutonium for weapons, and the facility itself could readily be turned to that purpose if the state withdrew from the Nonproliferation Treaty. Any subnational group that had the capability to do the technically challenging job of making a bomb from pure plutonium would likely be able to do the much less demanding job of getting pure plutonium from this uranium-plutonium mixture if it were stolen. Hence the shift from PUREX to COEX-type processes offers only very modest benefit in reducing proliferation risks. Similarly, while a facility to carry out one of the UREX+ family of processes could be designed so that modifications to produce pure plutonium would be readily detectable, having such a facility would significantly reduce the time and cost for a country to produce plutonium for a weapons program. And in most scenarios, the radiation from the UREX+ product would not be sufficient to deter determined terrorists from stealing this material, or to prevent them from processing it to get bomb material.

*Question 3.* Can you please explain what safeguards will be required for the use of MOX fuel as outlined by the NRC? Will they add cost to commercial light water reactors?

Answer. DOE's contractors have asked for, and NRC has granted, substantial exemptions from NRC's rules for physical protection of Category I nuclear materials for the use of MOX fuel. I believe that some variations in physical protection approaches are warranted for a nuclear reactor using fabricated MOX fuel as compared to a facility processing HEU metal, but that the exemptions in this case went too far, and were granted without adequate consideration of the likely impact they would have on U.S. efforts to convince other countries to maintain high levels of security for separated plutonium and MOX. With these exemptions in place, the additional safeguards costs for reactors using MOX fuel are modest, though plants will incur high fabrication costs and some license amendment costs.

*Question 4.* What are the estimated usage capacities of reprocessing plants around the world?

Answer. The Thermal Oxide Reprocessing Plant (THORP) in Britain has operated at much less than its design capacity for much of its life, because of a series of technical problems, culminating a few years ago in a leak into the basement of a swimming pool's worth of radioactive solution, which was not correctly identified for months. While THORP is now back on-line, it is expected to shut by 2012 because there are not enough contracts to keep it afloat. The French reprocessing plants at La Hague are operating at somewhat more than half their design capacity, primarily for Électricité de France, because few foreign utilities are any longer willing to contract for their reprocessing services. The Russian reprocessing plant at Mayak has also been operating well below capacity for years, because of limited contracts. The Japanese plant at Rokkasho is still in testing, which has been substantially delayed.

*Question 5.* Can you explain the surcharge imposed by utilities from the Japanese reprocessing plant?

Answer. When the full scope of the estimated costs of the Rokkasho reprocessing plant became clear—over \$20 billion in initial capital cost, and tens of billions more over the plant's projected lifetime—the Japanese nuclear utilities told the Japanese

government that they simply could not afford it, and asked for a bailout in the form of an additional charge to all electricity consumers, nuclear or non-nuclear. This will lead to an additional cost to consumers of tens of billions of dollars as a result of the construction and operation of the Rokkasho plant.

*Question 6.* Can you please explain fuel leasing as a means to avoid countries undertaking a fuel cycle?

*Answer.* An enterprise that could offer to provide fresh nuclear fuel, and then take away the spent fuel after irradiation could be a major breakthrough both for the future of nuclear energy and the future of nonproliferation. Nuclear energy would become more attractive to smaller countries that had never built nuclear plants before if they could have nuclear plants without needing their own nuclear waste repository. The opportunity to avoid having a nuclear waste repository would be a powerful incentive for countries to rely on the services of such an enterprise rather than producing fuel for themselves. Such an enterprise could include services from more than one country—and in particular, the country or countries that provided the fresh fuel and the country or countries that took the irradiated fuel would not necessarily have to be the same.

*Question 7.* Do you support research on fuel cycle separations? Would you support pilot scale demonstration of promising separation technologies?

*Answer.* I support a broad nuclear energy research program that would explore improved approaches to both open and closed fuel cycles. This would include research on separations, focusing particularly on exploring whether advanced technologies might have the potential to overcome the large economic and proliferation liabilities of traditional reprocessing approaches. This should include a range of approaches going well beyond those currently being pursued in GNEP, including, for example, fluoride volatility and supercritical CO<sub>2</sub> technologies, along with approaches for continuous partial reprocessing, as were once proposed for the molten salt reactor.

#### RESPONSES OF MATTHEW BUNN TO QUESTIONS FROM SENATOR DOMENICI

*Question 1.* Given all the political obstacles, escalating cost estimates and finite capacity of Yucca Mountain, and the growing DOE liability for failure to take possession of spent fuel, what do you think is the right U.S. waste management strategy going forward?

*Answer.* I support the bipartisan recommendation of the National Commission on Energy Policy, which I recommend that we follow the advice of the bipartisan National Commission on Energy Policy, which reflected a broad spectrum of opinion on energy matters generally and on nuclear energy in particular, and recommended that the United States should:

- (1) “continue indefinitely the U.S. moratoria on commercial reprocessing of spent nuclear fuel and construction of commercial breeder reactors”;
- (2) establish expanded interim spent fuel storage capacities “as a complement and interim back-up” to Yucca Mountain;
- (3) proceed “with all deliberate speed” toward licensing and operating a permanent geologic waste repository; and
- (4) continue research and development on advanced fuel cycle approaches that might improve nuclear waste management and uranium utilization, without the huge disadvantages of traditional approaches to reprocessing.

Several points concerning Yucca Mountain are important to remember. First, the nation will need a nuclear waste repository regardless of whether it pursues reprocessing and recycling or direct disposal. Second, the cost of dry cask storage for decades is much smaller (by a factor of 4–10) than the cost of reprocessing. When the full life-cycle is considered, it is still the case that reprocessing and recycling this spent fuel would be substantially more expensive than disposing of it without reprocessing. Hence shifting to reprocessing would increase, not decrease, the cost to the government of addressing its liability for managing spent fuel. Third, the physical capacity of the Yucca Mountain repository is very much larger than the legislated capacity—and is likely to be sufficient to support a growing U.S. nuclear energy enterprise based on direct disposal for many decades to come. Fourth, the difficulties of siting and licensing several large reprocessing and fabrication plants and scores of fast neutron reactors, required to implement the GNEP vision as currently proposed, may be even greater than the difficulties of siting and licensing an additional repository, if and when one is needed in the future. To move toward near-term reprocessing now would put us on a path that would be more costly, more complex, less safe, less terrorism-resistant, and less proliferation-resistant than the al-

ternative; in my judgment such a step would undermine, rather than promoting, the future of nuclear energy.

*Question 2.* In your previous testimony you referred to “fuel leasing” arrangements as, and I quote, “an important and potentially powerful idea, which should be pursued” for their nonproliferation benefits. But then you state that it is Russia that should lead this effort. That the U.S. simply can’t do it. Why is it that the U.S. can’t do it? So we should leave a “potentially powerful” nonproliferation initiative for Russia to implement? If the US cannot perform “domestic spent fuel take back” how can it offer foreign services?

*Answer.* I believe that importing large quantities of foreign spent nuclear fuel into the United States is not politically realistic at present. Even taking back small quantities of irradiated research reactor fuel, which had a very compelling nonproliferation purpose, generated substantial controversies and lawsuits when the program was renewed in the 1990s. I wish it were otherwise, and I believe the U.S. government should be working to build support for importing at least limited quantities of spent fuel from countries that might build one or two reactors, as part of such a leasing arrangement. As I noted above, however, in a fuel leasing enterprise there is no essential need for the country or countries that accept the spent fuel to be the same as the ones that provided the fresh fuel. We should be working with Russia (which has already adopted legislation making fuel leasing possible) and other countries around the world with the goal, over the decades to come, of siting and licensing a small number of storage sites and repositories that could be used by countries around the world. While the politics of one country taking another country’s nuclear waste are extraordinarily difficult, they are not insurmountable in the long term, and it is important to seek to move forward. Ultimately, it simply does not make sense for each of the dozens of countries that have one or two nuclear power plants, or even a single nuclear research reactor, to build its own nuclear waste repository.

It is important to note, in any case, that reprocessing is not required to make an offer of fuel take-back. Once the spent fuel had been removed from a particular country, that country would not be likely to care one way or another whether the fuel was eventually reprocessed. Even if the fuel were reprocessed, the country that accepted the spent fuel would still have to dispose of the resulting radioactive wastes, raising the political problems of disposing of other country’s wastes—unless these wastes were sent back to the country that had used the fuel, which would eliminate the large benefit of that country not requiring its own repository, and would make the “leasing” operation no better than the commercial reprocessing services already offered by Britain, France, and Russia.

*Question 3.* Your testimony clearly demonstrates that you are very knowledgeable in nonproliferation policy and you follow the nuclear fuel cycle developments very closely. As such, you must know the difficulties we will have in developing the Yucca Mountain project. The politics and the economics seem to defy commonsense as does the current budget. Your testimony states that you believe GNEP will make it more difficult to site Yucca. With all due respect Dr. Bunn, how can you further complicate a project that will open at least 20 years late if at all? You also propose expanding Yucca to the next ridge over. What do you believe the likelihood of that happening what do you suppose the cost might be for such a project?

*Answer.* It is indisputable that there have been decades of delay on the Yucca Mountain project. There is at least some reason for hope, however, that the light at the end of the tunnel is coming into view—but that end could be thrown into doubt by GNEP. Currently, the Department of Energy is working to prepare a license application for the Yucca Mountain repository. That application is based on direct disposal of spent nuclear fuel and of defense wastes. A decision at the last minute to radically change the type of material to be disposed of in Yucca Mountain, and to hold open the possibility of radically increasing the quantity of nuclear electricity whose waste would be disposed of there, would inevitably complicate the process of getting to an initial license.

The latest Department of Energy analyses indicate that while the estimated costs of Yucca Mountain have grown, it remains fully funded by a 1 mill/kilowatt-hour fee. It is very likely that a second repository, if and when one was ever needed, would be less costly, per unit of wastes emplaced, because it would be able to draw on a huge body of preparatory work done and lessons learned in developing Yucca Mountain. Hence the 1 mill/kilowatt-hour fee would likely remain adequate (though some adjustment for inflation over time, which has not yet occurred, may eventually be needed). A second repository might simply make use of a next ridge over at Yucca Mountain, in which case a large amount geologic analysis done for Yucca Mountain would still be relevant. Or, a second repository might be located elsewhere, possibly in an area with reducing chemistry (as all other advanced nuclear

states appear to be pursuing for their nuclear waste repositories). A different site would also make it possible to choose a location in a large area of rock without the physical capacity constraints that exist at Yucca Mountain. There is no doubt that siting and licensing a second repository would be an enormous challenge but siting and licensing multiple large reprocessing and fabrication plants, and scores of fast neutron reactors (all of which will pose greater safety hazards to the current generation than an underground repository will) may be an even more difficult challenge.

Moreover, if the United States moved toward reprocessing, recycling, and transmutation, as proposed in GNEP, the economic costs would be significantly higher (particularly if the capital cost of fast reactors remained higher than that of thermal reactors, as has been the case for decades). The 1 mill/kilowatt-hour fee would have to be substantially increased, or onerous regulations would have to be put in place requiring industry to finance uneconomic facilities, or the government would have to commit to sustained subsidies over many decades, likely to total tens or hundreds of billions of dollars.

*Question 4.* Recently the CBO has estimated that the \$57B price tag for the Yucca Mountain project could grow by as much as 40%—or \$23 B, which is 2x the marginal cost CBO estimates that a recycling facility might cost. This doesn't count the growing federal legal liability, which CBO estimates will add \$1.3 billion annually to the cost of the project. When you developed your cost analysis of recycling technology what was the cost figure you included for Yucca Mountain as a comparative? In light of what the CBO has testified to, how might this impact your economic analysis?

*Answer.* As I noted earlier, estimates of the costs of Yucca Mountain have increased, but the latest DOE analyses conclude that the project remains fully funded with the 1 mill/kilowatt-hour fee. I note that CBO concluded that reprocessing and recycling would be significantly more expensive than direct disposal including their increased estimate of Yucca Mountain cost. It is also important to recognize that the traditional approach to recycling, in which the fuel is reprocessed, used as plutonium-uranium mixed oxide (MOX) fuel in thermal reactors, and then not reprocessed further, results in virtually no increase in repository capacity, because of the buildup of heat-emitting isotopes in the irradiated MOX fuel; nor does this approach significantly reduce the expected doses to humans and the environment per kilowatt-hour of electricity generated. It offers, in short, high cost and significant proliferation risk with virtually no benefit. GNEP, by contrast, envisions gaining large repository benefits by repeated recycling in fast reactors—but a range of studies have concluded that the more complex separations and fabrication processes envisioned would lead to even higher costs than traditional reprocessing. In our 2003 study, we concluded that the net present costs of future repository space would have to increase to some \$3,000 per kilogram of heavy metal, many times current cost estimates, to make this approach economically competitive on the basis of reduced repository cost.

*Question 5.* In your closing you state that dry cask storage is a perfectly acceptable solution for our near term waste strategy. Where would you propose to locate the consolidated spent fuel site and based on what you know about Yucca Mountain acceptance in Nevada, what do you suppose the chances are of permitting such a site?

*Answer.* Safe, cost-effective, and proven dry cask stores have already been established at many nuclear plants in the United States. Nevertheless, I believe there is a need for at least some centralized storage capacity, especially to take the fuel from sites that have been decommissioned, so that those sites need no longer be maintained as nuclear facilities. The bipartisan National Committee on Energy Policy and the recent American Physical Society panel on spent fuel management reached similar conclusions.

There is indeed a long, unsuccessful history of efforts to site and license a centralized storage facility for spent fuel in the United States. We outlined this history in some detail in our 2001 study, *Interim Storage of Spent Nuclear Fuel*, written with colleagues at Tokyo University. In that study, we outlined in detail a more democratic and cooperative approach to siting and licensing such facilities, based on other groups' earlier work on a "facility siting credo," which I believe would have significantly higher chances of success. Technically, there are a huge number of places in the United States where such facilities could be located.

*Question 6.* GNEP provides a way for countries to implement their fuel cycles together. Not every country needs their own enrichment and reprocessing facilities. These facilities are indeed sensitive from a proliferation perspective. If we can offer these services to states won't this reduce proliferation risks?

*Answer.* A vision focused on U.S. reprocessing is not required for offering other countries assured fuel cycle services, and is counterproductive to the effort to con-

vince countries not to build reprocessing plants of their own, as I outlined in my testimony. Reprocessing is irrelevant to the effort to offer assured supplies of fresh fuel. As I have noted above, reprocessing is not required to take away other countries' spent fuel. But to change the U.S. message from "reprocessing is not needed, we do not do it and you do not need to either" to "reprocessing is essential to the future of nuclear energy, but we will keep the technology from you" is likely to make it more difficult, not less, to convince states such as South Korea and Taiwan (both of whom have had secret nuclear weapons programs based on reprocessing in the past) not to pursue reprocessing plants of their own.

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RESPONSES OF PETER R. ORSZAG TO QUESTIONS FROM SENATOR BINGAMAN

*Question 1.* Can you please explain your assumed discount rate—would you expect it to be higher based on risk?

Answer. CBO's analysis used a 3.5 percent real discount rate, which is between that used in the Boston Consulting Group (BCG) and the Kennedy School studies. That rate is roughly consistent with that used by CBO in other investigations when evaluating the costs of other government financed programs. If the risk of the reprocessing project were to reflect private sector financing, the discount factor used would be greater than the value used in CBO's analysis, and the cost of the reprocessing option would be correspondingly higher.

*Question 2.* How sensitive are your results to the cost of the facility—typically first of a kind nuclear facilities exceed initial estimates, the MOX facility the NNSA is building one example.

Answer. The cost to build and operate the reprocessing facility exerts a substantial influence and drives much of the difference in the \$5 billion to \$11 billion range reported by CBO. That range reflects differences between the two studies on which CBO built its analysis. To the extent that costs of a reprocessing facility would exceed initial estimates, which is possible given the limited number of reprocessing plants that have ever been built worldwide, the relative cost of reprocessing would be towards the higher end, or perhaps above, the range that CBO reports.

*Question 3.* Can you please explain your assumptions about how densely packed the waste forms are in the repository and its sensitivity?

Answer. Three broad types of waste must be accounted for to compare the cost of reprocessing with those of direct disposal: spent nuclear fuel from uranium used one time, high-level wastes from reprocessing after the separation of plutonium and uranium, and spent fuel that had been previously reprocessed. The main limitation on the capacity of a long-term geologic repository is the heat content of the waste to be stored. After a period of interim storage, reprocessing wastes are cooler than spent nuclear fuel, but spent previously recycled fuel is hotter than either of the other two.

By assuming that spent previously recycled fuel would be handled separately, the two studies that CBO focused on both assumed that that reprocessing reduces geologic storage requirements compared to direct disposal. Accordingly, a repository would accommodate more reprocessing waste than spent fuel used once by packing the cooler waste more densely. CBO's analysis assumes that reprocessing wastes can be stored 2.5 times more densely than spent nuclear fuel, a value between those used in the BCG and Kennedy School studies.

*Question 4.* Part of your analysis includes a credit for reusing the spent nuclear fuel in reactors, how accurate and how sensitive is such an assumption?

Answer. Recycled plutonium and uranium would be potential sources of revenue, sometimes known as "fuel credits," that could offset some of the costs of the reprocessing plant and reduce the cost differential between reprocessing and direct disposal.

The value of those fuel credits depends on the costs of recovering and preparing newly-mined uranium for reactor use and the willingness of reactor operators to make the investments necessary to modify their reactors so that they can use reprocessed fuel. If the costs of new fuel were higher, then the value of recycled fuel would also be higher. If reactor operators make the investments necessary to use reprocessed fuel, then the market for that fuel will be accordingly stronger. The BCG study included adjustments for that factor in its calculation of fuel credits.

Current uranium spot prices are near historical highs after a recent price run-up, though uranium prices have declined by about a third since the summer 2007 peak. For such prices to have a material impact on the cost of reprocessing, those high prices would have to persist for decades. There is little indication that high prices should be expected to continue for years to come or that uranium is in limited supply over the long term.



## RESPONSES OF PETER R. ORSZAG TO QUESTIONS FROM SENATOR DOMENICI

*Question 1.* Given all the political obstacles, escalating cost estimates and finite capacity of Yucca Mountain, and the growing DOE liability for failure to take possession of spent fuel, what do you think is the right U.S. waste management strategy going forward?

Answer. CBO's analysis compares the economic costs of reprocessing nuclear waste with those of the direct disposal of that waste. Although reprocessing reduces expenditures on uranium mining and preparation costs, and may reduce long-term storage costs, the balance of the cost evidence suggests that reprocessing is likely to be more costly than direct disposal. That result reflects the fact that dedicated reprocessing facilities need to be built and that some form of long-term storage remains necessary under reprocessing.

To address the question of what is the right waste management strategy for the United States, policymakers also need to weigh a variety of factors besides the cost of reprocessing compared to direct disposal in the context of nuclear reactors currently in operation. Those other factors include the costs and benefits of adopting new reactor technologies and the consequences of the nuclear fuel cycle adopted by the United States for the proliferation of nuclear weapons.

*Question 2.* In your "split the difference" analysis the additional cost of recycling is \$5-\$11B. However, this is the cost for fuel produced in the future, and assumes that a second repository is built for what DOE estimates it will cost to physically build Yucca Mountain.

First of all, I'd like to point out that CBO recently testified that DOE estimates that Yucca Mountain will cost \$57.5 billion, with a "range of accuracy of plus or minus 40 percent." In other words, the "margin of error" on this number is \$23 billion, more than twice the higher CBO cost estimate for recycling.

Further, CBO recently testified in the House that the government's contractual liability for its failure to take spent fuel in 1998 will grow to \$7 billion if Yucca Mountain opens in 2017, and \$11 billion if it opens in 2020. This translates into about \$1.3 billion per year.

But here's my question: Does your analysis include any impacts on the costs of management of the existing stockpile of fuel, including the \$1.3 billion per year cost to the taxpayer of DOE's failure to move waste, or the savings if a second repository can be avoided altogether?

Answer. The federal government is likely to incur management costs on the existing stockpile of fuel for years to come under either scenario. Under current plans, storage costs must be covered while a long-term solution is being considered and developed. Under a reprocessing scenario, the federal government would incur similar costs while a reprocessing facility was being developed. Such development requires years of construction and significant delays are possible, as the Japanese Rokkasho reprocessing plant experience has shown. Similarly, reprocessing would not likely delay or eliminate the need for a second repository under current law. The Nuclear Waste Policy act of 1982 legislates the capacity of Yucca Mountain to be 70,000 MT of spent nuclear fuel or "a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent fuel."<sup>1</sup> The amount of spent fuel, rather than the existence of a reprocessing facility, determines whether a second long-term repository would be needed.

*Question 3.* You estimated a repository cost of \$1,036 per kilogram of spent fuel. This was considerably higher than the estimates for the Kennedy study (\$868) and the BCG study (\$736). Can you tell me how you arrived at that value? Why are estimates for Yucca Mountain all over the map?

Answer. CBO's analysis of the cost of disposing of nuclear waste uses the methodology developed in the BCG Study, but is estimated with the most recent cost and schedule data provided by the Department of Energy's Office of Civilian Radioactive Waste Management (OCRWM). The BCG methodology differs from the approach used in the Kennedy School study, which calculated the cost of long-term storage based on the 1 mil (one tenth of a cent) per kilowatt-hour surcharge on electricity produced by commercial nuclear reactors. Although OCRWM deemed that surcharge adequate in 2001 to cover the life cycle cost of Yucca Mountain, the surcharge and those costs can not be directly linked and, thus, the unit cost estimates need not match. Thus, the difference in the estimates of the cost of Yucca Mountain between the BCG study and the Kennedy School study and those studies, and CBO's estimate reflect both different methods, and CBO's choice to use the most recent data available.

<sup>1</sup> Nuclear Waste Policy Act of 1982, Section 114(d).

*Question 4.* What is the percentage difference in terms of overall costs between recycling and once-through and how relevant is that, considering the uncertainties involved in making these assessments?

Answer. Based on a review of the BCG and Kennedy School studies, CBO finds that the cost of reprocessing is expected to be at least 25 percent more costly than direct disposal. CBO conducted a sensitivity analysis of key assumptions and found that in almost all cases was reprocessing more costly than direct disposal.

One uncertainty is the construction and operating costs of the reprocessing facility. Historically, there have been few commercial reprocessing facilities in operation and publicly available cost information is less numerous. However, the historical record of reprocessing plants has been that they have operated considerably less than full capacity and they have proved more costly than initially planned, either of which increases the cost of reprocessed relative to direct disposal.

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RESPONSES OF TERRY WALLACE TO QUESTIONS FROM SENATOR BINGAMAN

*Question 1.* We have developed large scale computers in the stockpile stewardship program, can you explain the advantages of using these machines to model to the development of separations processes?

Answer. Application of large-scale computing to the GNEP program and in this case the separations process is essential to expediting the long-term process development. It is not just the computer hardware but also the methods and simulation capabilities that were developed under the stockpile stewardship program that provide a scientific foundation to address new applications such as the fuel separations process. To characterize better how the current and future capabilities can be applied, the problem can be broken down into two parts. The first is the scientific methods and capabilities developed under stockpile stewardship that can expedite development of many applications. The second part is the application itself, which in this case is the separation process.

To expedite the development process, the methods and capabilities will accelerate the testing process. These capabilities can also be utilized in the short-term employing existing models of the applications. Depending on the complexity of the application simulations, these tools require large-scale computing resources to execute many simulations that span the potential design and development space, or for less complex simulations the use of workstations can be informative. The results of the analysis of these simulations provide a quantitative basis to:

- a. guide experimental and modeling investments that minimize the total development time required,
- b. minimize the total number of experiments required by specifically designing experiments to address results from item a, and
- c. minimize predictive uncertainty and increase the confidence in predictive capability. The latter result allows us to minimize risk and provides the basis for possible licensing activities.

While further investment is needed in these methods and capabilities as the complexity of the simulations increase, our current capabilities provide an excellent basis from which to begin work today.

Regarding the modeling of the separations process, the current strategy for future separations modeling progresses from the microscopic scale to the macroscopic scale. The micro-scale models allow us to characterize material properties at a more fundamental scale that are then used in conjunction with macro-scale (engineering scale) simulations, e.g. aqueous separation techniques where fluid-flows are present. Both micro-and macro-scale simulations will require large-scale computing in the long-term. This need for computing at the micro-level derives in great part from the fact that it will require first principle techniques, those at the quantum level, because there are no particularly good force fields for the heavy elements involved. In particular, molecular dynamics (MD) simulations of the interactions that govern the chemistry of the process can take advantage of such computing resources, particularly when combined with accelerated MD methods, which allows for simulations of longer time periods. Thus a goal of the current modeling, simulation and computing capabilities is to allow us to represent a potential process and evolve it to a better process through modeling and simulation and then use fewer experiments to validate the process model or guide improvements.

The approaches that have been described are not unique to the separations process and can be extended to other aspects of a closed-fuel cycle. We are certain that significant future challenges will exist in any of these areas, but we believe the approaches, developed as part of the stockpile stewardship program, when coupled

with LANL's broad experience in science, engineering, simulation, and large-scale computing, can provide solutions to a number of important national issues.

*Question 2.* Are there technologies short of building a fast reactor we could use to understand the burn up of fuels made from separated spent fuel? How extensive a program do you recommend in this area before building a fast reactor?

There are two technology options available in the near term in the US for testing of fuels and materials in a fast neutron energy spectrum: 1) implementation of the Materials Test Station at the Los Alamos Neutron Science Center (LANSCE), and 2) use of existing thermal reactors with special "filters" to partially reduce nonprototypic thermal neutron exposure. Implementation of the Materials Test Station is relatively inexpensive (\$30M per year over three years for a total of \$90M, followed by annual operating costs of \$10M) and will provide a test environment that is very prototypic of fast reactors. With the MTS, laboratory and university scientists will obtain critical data that are needed to develop the advanced fuels and materials for the transmutation of spent nuclear fuel. These data will be used to validate the predictive computer models that will be developed as part of an integrated program (see response to question above). In addition to fulfilling the fuels and materials test requirements, the MTS will be used to achieve other scientific breakthroughs needed to develop materials for fusion reactor first-wall applications, and will provide a unique source of isotopes for nuclear medicine research. The MTS will be operated as a national user facility, providing a unique environment for scientific research.

Outside the US only a small number of existing fast reactors could be used to conduct advanced fuels irradiation tests (JOYO in Japan and BOR-60 in Russia). However, the US has no control over the use of these reactors and the priority that would be given to US tests. In addition, it was recently announced that the JOYO reactor will soon be shut down for two years. Experience with conducting fuels tests in foreign test reactors shows that such tests are expensive and administratively complex, requiring extensive government-to-government arrangements that require long lead times to put into place.

The construction of a new fast reactor (Advanced Recycling Reactor) in the US will take 15 years, and cost about \$2B. We believe that to offer the best chance of success, the US should take a measured approach and enter into a cooperative agreement with other countries that share similar goals. An international project (similar to the ITER fusion reactor) would allow us to leverage the wealth of experience in fast reactor technology that exists abroad. Concurrent with this activity we recommend implementation of the Materials Test Station over the next three years followed by a robust experimental program (conducted over approximately ten years). In addition, the current unfiltered thermal neutron irradiation experimental program being conducted under GNEP with the Advanced Test Reactor in Idaho should be continued. Although the test environment is not perfect, some data will be obtained in the interim that will advance the understanding of advanced fuel performance.

*Question 3.* What safeguards research do you recommend for the separation of spent fuel?

Answer. As the nuclear fuel cycle evolves, it is important that safeguards and nonproliferation technology evolve and respond accordingly (from both a domestic and international perspective). Research and technology development for advanced safeguards for the separation of spent fuel requires a broad based, multi-disciplinary, integrated experimental and computational effort. In particular, advances are needed in the following areas:

a. Advanced instrumentation—adaptation of established approaches to address unique aspects of advanced fuel cycle materials (for example measurement of plutonium in the presence of minor actinides); development of new approaches that build on a foundation of the generation of basic data (for example correlations between fission gamma and neutron emission in energy and time requires expansion of the existing nuclear physics database); online instruments (radiation and non-radiation based) that can dramatically reduce the number of samples required for offsite chemical analysis (while chemical analysis yields the most accurate results, taking samples is costly and results are not timely).

b. Systems analysis—tools are needed to optimize the safeguards system design, incorporating details of the chemical process in addition to tracking mass flows, these new tools will incorporate a range of disparate data in a quantitative sense to enable near real time knowledge extraction of facility operations (for example, combining nuclear material measurements, process monitoring data, video, personnel locations, etc. in a manner such that different configurations can be compared with regard to efficiency and efficacy); evaluation

of the fuel cycle system in terms of proliferation risk reduction at site, region, and global scales; specific analyses related to the evolving design basis threat.

c. Modeling and simulation—advanced modeling and simulation tools are required to support both instrumentation development and systems analysis; these tools must span a range of length and time scales from first principles (for example, integrated pulse counting and source term simulation for discovery and evaluation, engineered materials), to process simulations with enough fidelity to objectively evaluate new safeguards technologies and synergies between efficient facility operations and nuclear materials management; use of advanced visualization to aid in the distillation of rich data sets; incorporation of advanced modeling and simulation techniques across a range of computing platforms to enable R&D products to be applied in a variety of situations (work station, direct facility use).

LANL stands ready to make significant contributions in all of the above areas, bringing our broad experience in science and engineering to bear on this important national issue. In particular, the following institutional assets can be utilized towards this end:

a. Chemistry and Metallurgy Research facility hot cells can provide an integrated R&D test bed facility for iterative development in an uncontaminated environment, thus providing both technology advancement and risk mitigation prior to fielding expensive equipment in a real process facility (this capability could be combined with separations and fuel fabrication research efforts).

b. Los Alamos Neutron Science Center can generate basic physics data, particularly in the case of new data that can enable discovery of novel techniques (for example, neutron and gamma fission multiplicity distributions, nuclear fluorescence cross sections).

c. Advanced Simulation and Computing program investments at LANL have resulted in significant computing capability, enabling new levels of simulation fidelity and providing potential for a virtual laboratory where evaluation and optimization of new safeguards technologies can be made; existing visualization techniques can provide benefits ranging from realistic and immersive inspector training to assessment of new data integration and analysis techniques for holistic facility performance assessment.

#### RESPONSES OF TERRY WALLACE TO QUESTIONS FROM SENATOR DOMENICI

*Question 1.* In your testimony you noted that Los Alamos has developed some of the leading computational capabilities used to model reactor physics yet neither the Department nor the labs have developed advanced computational tools able to simulate the separations processes involved in recycling. The same is true with fuel fabrication processes. What is involved in developing such a simulation capability and can Los Alamos develop this computational capability?

Answer. Los Alamos is currently involved in developing these simulation capabilities as well as the hardware capabilities that are required, such as the petaflop level of computing as represented by the proposed Roadrunner machine.

To explain what is involved, the approach used in past decades prior to our current level of computing became available should be briefly described. Models of either the fuel fabrication process or separations process were built with a heuristic (or empirical) approach based on experimentation, where the experiments were as prototypic as possible. In short, the process defined an experiment, and experimental results were used to build the model/simulation that could be used to study the process. To define a new different process would require new experiments, etc.

Today, as a result of the large-scale computing capabilities that have been developed as part of the stockpile stewardship program, we are able to develop capabilities on a more first-principle basis. This has effectively allowed us to revise the older approach noted above. We employ theory, modeling, simulation, and experimentation in a much more integrated manner and define focused experiments to improve the theory and modeling or to assess the validity of the theory and model. Key to this capability is high-performance computing (at the 100 teraflop and petaflop speeds), with which we can now begin to do atomistic and molecular-scale simulations. These computing speeds and micro-levels of modeling allow us to characterize material properties at a more fundamental scale that in turn are used in conjunction with our macro-scale (engineering scale) simulations, for example in the areas of fuel fabrication and separation. Thus, our current modeling, simulation, and computing capabilities allow us to analyze a potential process and develop it into a better process through modeling and simulation and then use experiments to validate the process model or guide improvements.

These new capabilities, which we are starting to apply to fuel fabrication and fuel performance and to separations, are essential to expediting the development process. Results provide a quantitative basis to:

- a. guide experimental and modeling investments that minimize the total development time required,
- b. minimize the total number of experiments required by specifically designing experiments to address results from item a, and
- c. minimize predictive uncertainty and increase the confidence in predictive capability. The latter result allows us to minimize risk and provides the basis for possible licensing activities.

LANL stands ready to make significant contributions in the above areas by applying our broad experience in science, engineering, simulation, and large-scale computing.

*Question 2.* Can science and technology eliminate the need for a second repository?

Answer. Yes, but probably only under the scenario of a closed fuel cycle, and only if R&D is conducted to reduce uncertainty in the long-term performance of closed-fuel-cycle waste forms and engineered systems.

This answer presupposes that the Yucca Mountain repository is successfully licensed, and that legislation is passed to change the current restrictions regarding repository capacity. The current legislated capacity, measured as the total metric tons of heavy metal (MTHM), is inherently an open fuel cycle concept that conservatively limits how densely the spent nuclear fuel rods can be packed underground so as to not exceed temperature limits for the emplaced waste and surrounding rock. Under a closed fuel cycle, engineered waste forms with far less long-term heat output would be produced and disposed. With efficient separations and reprocessing, Yucca Mountain would have no practical heat-management constraints to disposing the waste from a much larger nuclear enterprise. The other technical issue for disposal of larger quantities of waste at Yucca Mountain than currently planned concerns the issue of long-term waste isolation capability. Here a closed fuel cycle envisioned under GNEP promises significant benefits, in that the long-lived, dose-contributing isotopes of plutonium and americium, as well as neptunium-237, will be recycled and consumed in fast reactors. This strategy improves the long-term performance of the repository for a given amount of disposed waste, or, alternatively, allows the waste from a larger quantity of generated power to be disposed safely, without exceeding performance limits. Finally, the separations processes envisioned under GNEP will be combined with R&D on new waste forms that can be designed to enhance the isolation capability of Yucca Mountain. With a focused research program, materials selected to withstand the Yucca Mountain environment can be designed to incorporate problematic radionuclides in a form that limits their escape into the groundwater.

*Question 3.* What do you think the R&D priorities should be for radioactive waste management?

Answer. R&D needs in the areas of separations technologies and the development of new waste forms should be the highest priorities. Also, additional R&D focused on making Yucca Mountain safer and less expensive should also be conducted. These R&D efforts will enable us to develop cost-effective, safe, and proliferation-resistant processes for closing the fuel cycle.

The main objectives for the separations system for spent reactor fuel under development within the GNEP program are to reduce the proliferation risk of the fuel cycle relative to the current practice and to extend and enhance the use of the U.S. geological repository capacity by: 1) recycling of the minor actinides to recover energy, and 2) reducing the volume, long-term radiotoxicity, and heat load of the waste placed in a repository. The UREX+ suite of solvent extraction processes that have been developed within the GNEP program provides these benefits, and these processes have been demonstrated with LWR spent fuel at the level of kilograms per test run. Further development work, including the baseline extraction systems and product and waste form preparation, is required. These processes need to be run in an integrated fashion, and at much larger scales and for extended periods, for industry to have the information required to design commercial scale facilities. Separation methods beyond the aqueous UREX+ extraction system should also be pursued, such as electrochemical processes in molten salts for recycle of fast reactor spent fuels. In the longer term, revolutionary separation processes that could substantially reduce the cost of the spent fuel recycling are possible, but the underpinning science must be established sufficiently to allow comparison of the new processes to existing options.

The second broad research priority is in the area of waste forms that sequester radionuclides within a solid matrix. The development of new waste forms with superior performance characteristics is within our reach, but it will require long-term R&D to reach maturity. These waste forms of the future can be developed using a scientific approach that leads to a first-principles understanding of materials properties through the joint application of experimental tests, theoretical studies, and computer modeling. To achieve this advance, dedicated facilities are needed to measure the mechanical and chemical properties of the solid waste forms under self-irradiation and to test the longterm resistance of the waste form to dissolution and release of radionuclides when exposed to groundwater of various chemical characteristics. Models that capitalize on the high performance computing capabilities available at the national laboratories would be developed and used synergistically with the experiments. Gaining a robust understanding of the mechanisms of failure of waste forms due to mechanical or chemical degradation will allow better waste forms to be designed and will greatly improve the confidence that can be placed in regulatory models used to license a waste form and repository disposal concept. The result will be more durable waste forms, lower predicted doses, and tighter uncertainty bounds on regulatory models.

In the area of repository R&D, the Yucca Mountain license application will present the safety case for the current design of the repository, which relies on a combination of engineered and natural barriers to prevent the exposure of the public to harmful radiation. Some costly engineered solutions have been put in place to mitigate the consequences of a failure of the geologic media to sequester radionuclides. More cost effective solutions are possible if additional science can be performed to ensure the validity of models of radionuclide mobilization and migration. R&D should be conducted to reduce the conservatism present in the models of the engineered and natural barriers, and to narrow the uncertainty ranges of those models. This research would serve two purposes. First, the repository as currently designed could be made more cost effective. Second, general research into repository performance, with a focus on testing designed to gain a more fundamental understanding of issues affecting longterm performance, would have beneficial impact on the projected use of Yucca Mountain as a repository for closed-fuel-cycle wastes. A cost-effective approach to conducting this research would be to integrate it with the NRC-mandated monitoring studies to be conducted under the Yucca Mountain Project Performance Confirmation Program.

*Question 4.* What is the state of U.S. leadership in nuclear technology? Are governments in France and Japan investing more than we are in nuclear research and development?

With few exceptions, the US has lost its leadership of nuclear energy technologies. Since the termination of the liquid metal fast breeder reactor program, spending on nuclear technology research and development has been in steady decline. In contrast, France and Japan have continued robust research programs at an annual level of five to ten times what the US is spending. For this reason they are far ahead of the US in large scale reprocessing and fast reactor technology-the very technologies needed to close the fuel cycle. Other countries are becoming involved in advanced nuclear energy technology development as well. Russia, China, and India all have advanced nuclear technology programs. For example, India will commission a prototype fast reactor in 2010 putting them substantially ahead of the US.

GNEP presents an opportunity for the US to re-engage in advanced nuclear energy technologies and to re-establish itself as one of the leading countries in the development of nuclear energy to meet the worldwide growing need for safe, secure, clean, and reliable energy.

*Question 5.* Given all the political obstacles, escalating cost estimates and finite capacity of Yucca Mountain, and the growing DOE liability for failure to take possession of spent fuel, what do you think is the right U.S. waste management strategy going forward?

We believe the best strategy is to safely and securely store the existing waste in interim storage while developing the technology for reprocessing, transmutation and closing the fuel cycle. Developing and locating one or two interim storage facilities may also run into political obstacles so in the near term, spent fuel storage must be accomplished at the existing reactor sites. As part of the technology development for closure of the fuel cycle, an integrated waste management strategy should be implemented. This strategy will look at all the wastes from the fuel cycle and develop the best and most robust waste forms that are designed to fit the environmental conditions of the repository. With the closed fuel cycle tied to the second repository there will be an opportunity to look at other repository media such as salt or clay.

The best path forward consists of two elements: 1) continue to support the current effort to license the Yucca Mountain repository, and 2) develop a robust R&D pro-

gram for advanced waste management within GNEP and other DOE programs. These elements must be designed to ensure that inadequate waste management solutions do not obstruct the expansion of nuclear power to meet our pressing need for safe, carbon-free energy sources.

Los Alamos scientists, in partnership with Sandia National Laboratories, the lead laboratory for post-closure science for the Yucca Mountain Project, are actively participating in the DOE's effort to prepare the license application for Yucca Mountain by June 2008 for consideration by the Nuclear Regulatory Commission. This milestone is an enabling activity for nuclear power to move forward in the U.S., either with a closed or an open fuel cycle, because it will demonstrate the will and ability of our country to make progress in solving the waste issue. The team in place is confident that a credible, defensible license application is being prepared that will withstand the intense scrutiny that it will undoubtedly receive.

Once the license application is submitted and the DOE, with help from the national laboratories and industry, begins to defend its conclusions, we should initiate studies that optimize the nation's waste management system, including the possibility of having the repository accept either spent nuclear fuel or the waste forms that will be produced in a closed fuel cycle. Yucca Mountain is an important component of this strategy, but the options go beyond Yucca Mountain to other geologic repository environments in the U.S. or abroad. Yucca Mountain could ultimately be used as currently designed, as the final resting place for commercial spent nuclear fuel in our current once-through fuel cycle, as well as serving as the nation's repository for Defense High-Level Waste. Alternatively, the commercial spent nuclear fuel emplaced at the site could be retrieved and reprocessed, and Yucca Mountain could ultimately become the repository for the closed-fuel-cycle wastes and Defense High-Level Waste that cannot be practically reprocessed. A hybrid solution with Yucca Mountain hosting a combination of closed-fuel-cycle wastes and once-through spent nuclear fuel is also possible. Note that all proposed alternatives to the current disposal plan for Yucca Mountain will likely result in better predicted long-term performance of the site, thereby making acceptance of these alternative proposals a simpler proposition than the ongoing post-closure licensing effort. Other considerations relevant to the technical and engineering feasibility of these options would need to be examined in systems studies and engineering analyses to ensure that this concept is viable from an operations perspective. The long-term R&D priorities for radioactive waste management outlined in the response to Question 3 above are an important element of this waste management strategy.

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#### RESPONSES OF PATTABI SESHADRI TO QUESTIONS FROM SENATOR BINGAMAN

*Question 1.* Your analysis indicates that disposal of MOX in a geologic repository is not considered a viable option because it could increase recycling costs by up to 40 percent. Can you please explain this?

Answer. Used MOX is a form of spent nuclear fuel. Spent fuel from Light Water Reactors (LWRs) is first reprocessed to create MOX fuel. The fabricated MOX fuel (recycled fuel) is then used in LWRs as nuclear fuel. Once the fuel is consumed or 'spent', it becomes a 'second generation' of spent nuclear fuel that needs to be further consumed or disposed.

Used MOX has several advantages. It still contains valuable nuclear energy content—the equivalent of at least 200 GWh of power generation potential for every ton of used MOX. This nuclear energy content can represent significant remaining economic value depending on prevailing nuclear fuel and power prices. It is also volumetrically smaller in quantity compared to conventional 'first generation' spent nuclear fuel. Foreexample, a reprocessing facility that processes 2,500 ton/year of spent nuclear fuel over 50 years leads to ~15,000 tons of total used MOX at the end of 50 years. This is a much smaller quantity relative to the ~55,000 tons of legacy nuclear fuel that has already accumulated at utility power plant sites over the past 30 years.

Used MOX also has a disadvantage. It is 'hotter' than conventional spent fuel-in that it contains a greater mix of plutonium and minor actinides such as americium. Therefore, any fuel management solution needs to consider how the used MOX will be consumed, stored or disposed.

In our analysis, we considered a variety of options to handle used MOX, including:

- i. long-term storage of used MOX at the recycling facility,
- ii. recycling of used MOX to generate new nuclear fuel,
- iii. burning used MOX in an Advanced Recycling Reactor (which can 'consume' long lived radioactive elements such as minor actinides), and
- iv. disposing of used MOX in a repository.

The economics of handling used MOX across these options vary widely. The list of options considered and a high level economic assessment of each is described in depth in Appendix A10 of the BCG report-attached to this response.

At one end of the spectrum, used MOX can (and has been) stored with a high degree of safety and certainty over very long periods of time, for example, at Areva's facilities at La Hague. Economically, this is the cheapest alternative to handle used MOX. Under this alternative, there will be very limited incremental costs to the recycling solution.

At the other end of the spectrum, if used MOX is disposed of in a repository, the 'densification' advantage is reversed. The densification factor for used MOX is ~0.15, which means that 150g of used MOX would take up as much space in the repository as 1 kg of used fuel. This approximately 6 times increase in the repository cost would be offset by the added time duration before which used MOX is disposed (~9 years after first generation spent fuel), and the lower total volume of used MOX relative to first generation spent fuel. Based on these factors, we estimated that the additional cost of used MOX, if directly disposed in a repository, would be ~\$200/kg. Under this scenario, this represents an increased cost of recycling of ~40% relative to a repository only solution. We consider this figure to be the upper bound for our estimates, but we do not include this figure in the sensitivity range, since disposal of used MOX is not considered to be a viable option.

Under some scenarios, used MOX could also provide positive value (i.e., reduce the overall cost of the recycling solution). As an example, as worldwide Uranium resources become tighter with significant usage/depletion over the next 70 years, used MOX as a source of nuclear fuel can have significant economic value to nuclear power plant operators.

Given the range of values possible, the BCG study assumed that the cost of used MOX disposal will be the same as the long-term cost of conventional spent fuel.

*Question 2.* How hard would it be to model the added cost of constructing fast reactors to your analysis?

*Answer.* The added cost of constructing fast reactors can be modeled with a modest incremental effort. The key inputs required are the capital, operating costs, operating parameters and estimated timing of fast reactor deployment. The modeling effort would also need to take into account the value of power production from fast reactors (i.e., there are additional sources of value that improve the overall economics).

As part of the GNEP business planning effort that engages industry and international players, the Department of Energy has asked four industrial consortia (respectively led by AREVA-MHI, EnergySolutions, GEHitachi, and GA) to develop business plans for nuclear fuel recycling in the U.S. Such business plans are likely to include an evaluation of fast reactor economics. Results from these initial deployment studies are expected to be made available to DOE in 2008.

*Question 3.* What was the discount rate you used in your model—can you please explain your assumptions?

*Answer.* The possible range of values for both the discount rate and the cost of capital are very broad, depending on the source of funding. Throughout the study we assumed that all the steps in the cycles are funded with public money, since the Department of Energy is legally responsible for the back-end of the nuclear fuel cycle. Therefore, we used the same public discount rate for repository and recycling solutions.

The value of the discount rate from public funding was triangulated based on historical real rate of return on long-term government bonds, and Office of Management and Budget (OMB) guidance. The data from these sources is discussed in further detail in Appendix A3 of our report. Based on these sources, we used a baseline discount rate of 3%.

As mentioned before, we assumed a similar discount rate for both the solutions in order to enable a pure economic comparison of the alternatives. As part of this study, we did not explore alternate business models such as public-private partnerships to implementing a recycling solution. We recognize that under the right contractual, legal and financial conditions, private entities would be willing to invest in some elements of the recycling value chain—most notably the recycling plant, but potentially also the transport system and all interim storage facilities.

While such alternatives are likely to incur higher financing costs, they would also provide financial benefits in the form of transfer of some risks to non-governmental entities. We believe that such a cost versus risk trade-off across business model alternatives should be valued separately from the basic cost economics of the two fuel management solutions.

*Question 4.* How did you value MOX in your calculations and how sensitive is your model to the economics of reprocessing?



Answer. The recycled fuel (both the MOX and the uranium-based recycled fuel, or recycled UOX) has a value and can provide a credit to offset some of the other costs. MOX and recycled UOX can be used in Light Water Reactors and are therefore comparable in value to UOX from mined uranium ore, after necessary adjustments for reactor adaptation costs, MOX acceptance costs and additional fuel enrichment, conversion, and fabrication costs. For each 1,000 ton of spent fuel recycled in an integrated reprocessing and fuel fabrication facility, the facility can produce approximately 120 tons of MOX fuel and 80 tons of recycled UOX.

The value of these two sources of nuclear fuel can vary based on prevailing Uranium prices, fuel fabrication costs, and the upfront costs required to prepare LWRs to accept MOX fuel. We estimated the combined value of these two sources of nuclear fuel to be approximately \$190/Kg. In this estimate, we assumed that the value of MOX fuel will be at a 25% discount to Uranium based fuel, to take into account the hard costs required for Light Water Reactors (LWRs) to accept MOX-based fuel and softer costs related to managing multiple vendors, and the like.

The \$190/Kg value of MOX and recycled UOX equates to approximately 25% of the estimated economics of recycling being driven by the value of fuel output from the recycling facility. Appendix A8 in the BCG report details the underlying assumptions and key drivers.

The primary driver of value for these recycled fuel sources is Uranium prices. The BCG study assumed long-term Uranium prices of \$31/lb. Higher Uranium prices will substantially increase the attractiveness of recycling economics. For example, spot Uranium prices over the last two years have averaged approximately \$75/lb compared to the 2000–2005 average of approximately \$14/lb. This included a peak price of approximately \$135/lb in 2007. The planned build out of new nuclear plants over the next 10–15 years has the potential to put further upward pressure on Uranium prices. Each \$10/lb increase in Uranium prices would represent a 3% improvement in recycling economics. Such indicators suggest that the BCG study potentially significantly undervalued the economic benefits of recycled fuel sources.

#### RESPONSES OF PATTABI SESHADRI TO QUESTIONS FROM SENATOR DOMENICI

*Question 1.* Given all the political obstacles, escalating cost estimates and finite capacity of Yucca Mountain, and the growing DOE liability for failure to take possession of spent fuel, what do you think is the right U.S. waste management strategy going forward?

Answer. Our study concluded that the economics of a repository only solution and a recycling-repository solution are comparable. Given the significant technical uncertainties related to a repository only solution, and the significant economic uncertainties related to both solutions, we believe the U.S. should pursue a portfolio solution to nuclear waste management. A portfolio approach to U.S. waste management strategy presents several compelling benefits, including:

- i. The potential to eliminate the need for additional repository capacity beyond the initial 83,800 ton capacity at Yucca Mountain, until the 2070 time-frame. In a repository-only approach, we estimated that an extension of Yucca Mountain capacity to its estimated technical capability of 120,000 tons would be required to dispose of fuel discharged after 2020 and an entirely new repository would be required for used fuel discharged after 2040.

- ii. Contribution to early reduction of used fuel inventories at reactor sites—in particular, removing newer, hotter fuel for recycling within three years of discharge and eliminating the need for additional investments in interim storage capacity at power plant sites. This has the potential to reduce government liability for failure to take possession of spent fuel.

- iii. The portfolio solution relies on existing technology with known improvements and modifications to enhance its effectiveness. This would be very similar to new nuclear power plant development where electric utilities migrate to subsequent generations of technologies over time rather than starting by scaling up one-of-a-kind technologies. Thus, a portfolio approach has the potential to significantly reduce implementation risks. It can also provide an operational transition to future technology developments such as Advanced Fuel Cycles and fast reactors.

- iv. Finally, a very important benefit of recycling is that it offers a tool for the nuclear power sector to protect against potential increase in uranium prices. The recycling approach produces MOX and recycled UOX fuel to nuclear power plants. We estimate that a recycling facility processing 2,500 tons/year of spent fuel would produce MOX and recycled UOX fuel equivalent to approximately 20–25% of the US nuclear power plant annual fuel requirements. The production cost of this fuel is, for the most part, independent of uranium prices and enrich-

ment costs. In addition, the facility would be located within the US, thus providing supply security for a portion of US nuclear fuel needs.

*Question 2.* In your analysis you found that if a portion of the existing spent fuel inventories and all of the newly generated fuel was recycled this would eliminate the need for a second repository and there would still be room in Yucca Mountain through the year 2070. Is that correct?

Answer. As mentioned before, in a repository-only approach, we estimated that an extension of Yucca Mountain capacity to its estimated technical capability of 120,000 tons would be required to dispose of fuel discharged after 2020 and an entirely new repository would be required for used fuel discharged after 2040.

The recycling-repository solution can indeed eliminate the need for a second repository through 2070, under the specific nuclear growth scenarios and size of recycling facility we evaluated.

Specifically, we assumed that there will be an installed base of 112GW of nuclear plants producing annual spent fuel of 1,800 tons per year. We called this a 'stationary' scenario where the existing 104GW installed base of nuclear power plants undergoes limited expansion over the next 20 years to 112GW based on the Energy Policy Act incentives. We also assumed that an additional 700 tons/year of 'legacy' fuel can be processed in dilution with the 1,800 tons per year in a recycling facility with total throughput of 2,500 tons per year. Under this scenario, the 83,800 tHM of estimated Yucca Mountain capacity from the 2001 DOE study would be sufficient to hold 50,000 tons of 'legacy' fuel and 30,000 tons of High Level Waste (HLW) from recycling through 2070.

We also evaluated a 'nuclear renaissance' scenario where the existing fleet of nuclear power plants is expanded up to 160GW by 2030. Such a significant nuclear deployment is more likely under a scenario in which stringent Carbon abatement legislation is enacted and spurs replacement of an estimated 100 GW of the U.S. generation over three decades—with nuclear gaining a significant share of those builds.

An increase in nuclear power generation of that magnitude would have the effect of significantly increasing the quantity of used fuel discharged, by about 30 percent above BCG current reference scenario of 2,100 tons/year. Even under these conditions, in the recycling-repository portfolio strategy, the integrated plant can accommodate all of the additional used fuel by not treating legacy fuel in dilution, as it was in the reference case. More legacy fuel would now have to be disposed of in Yucca Mountain. In this scenario we estimate that a total of approximately 100,000 tons of 'legacy' fuel and High Level Waste (HLW) from recycling would need to be disposed of in a repository through 2070. This scenario can be accommodated with a small expansion of an existing repository. As a reference point, the technical capacity of Yucca Mountain has been estimated in the 2001 DOE study as ~120,000 tons.

*Question 3.* The CBO estimates that there is a \$5B-\$11B additional cost for recycling over 40 years of operating a reprocessing facility—do you believe that it would cost more than this to build a second repository?

Answer. No cost estimates for a second repository beyond Yucca Mountain have been developed yet. Thus, absent any reliable cost estimate, the cost of the second repository in the economic assessment is assumed to be the same as the cost of Yucca Mountain (\$46B in 2005 dollars from the 2001 DOE lifecycle cost study: US DOE-Analysis of the Total Life Cycle Cost of the Civilian Radioactive Waste Management Program—2001). The uncertainty surrounding future costs of a second repository is significant. On the one hand, cost reductions driven by experience are conceivable, although building a second repository in a new geologic site would likely have very different features from the Yucca Mountain project. On the other hand, the very process of finding a suitable site and opening a new political dialogue could drive costs up significantly.

In this respect, the portfolio strategy, while sensitive to factors such as cost of the integrated recycling facility, cost of Yucca Mountain, uranium prices, additional cost related to management of used MOX, and discount rate—is not impacted by uncertainties surrounding the cost of a second repository, until at least 2070.

*Question 4.* Did your study or the analysis produced by CBO or Harvard consider the avoided cost of not attempting to site, construct and operate a second repository?

Answer. As mentioned in response to question 3, the BCG study assumed that a future repository would cost the same to construct and operate as estimated in the 2001 DOE economic study of Yucca Mountain costs. Additional potential costs of siting and constructing a new repository were not considered. In that regard, we did not include any benefits from avoided incremental costs.

*Question 5.* The CBO determined that another key difference between your study and Harvard's was in the construction and operation costs. Your study suggested certain "economies of scale" What was the basis of this assumption? Is this a common practice in estimating costs for other industries? Have other industries realized these unit cost reductions?

Answer. "Economies of scale" are a common driver of value in construction and operations in most industry sectors with significant capital base, and also in many non-industrial corporate administrative functions. For a given industry, company or facility's cost structure, "scale economics" are said to exist if an increase in volume requires less than a proportional increase in cost. For example, if the volume of a facility can be doubled without doubling total cost, then unit cost (i.e., average cost or cost per unit volume) falls as volume increases.

Common reasons why economies of scale exist include, fixed cost of setting up or operating a facility do not increase with size of facility, critical processes can be configured differently or more efficiently in larger scale facilities, purchasing economies come into play for major components, etc.

Virtually all industries and functions within a company exhibit some degree of scale economics. Other industries have certainly realized these unit cost reductions. For example, capital costs (measured on a \$/KW basis) for larger coal and gas-fired power plants are lower than those for smaller plants. In fact, these capital costs exhibit a 70–75% scale slope—in other words, every doubling of capacity reduces unit costs by 30%. Similarly, in ongoing plant operations there are significant economies of scale. As an example, non-fuel operating costs (a common measure of cost efficiency in power plant operations) are lower on a per MWh of power production in larger nuclear plants than smaller plants.

*Question 6.* What is the policy implication of rising Yucca costs as it relates to the recycling option the BCG study contemplates?

Answer. As mentioned in the BCG study, rising repository costs further reduces the economic gap between recycling and repository solutions. Furthermore, from a policy perspective, where there are cost uncertainties in two fundamentally different approaches, a portfolio solution that combines the two can provide important risk management benefits.

Portfolio solutions are common in situations where there are large capital outlays and there is significant uncertainty around the capital spend. For example, many companies in the utility sector are pursuing a portfolio of generation technologies—nuclear, clean coal, renewables and gas—to power the future needs of their customers. An easier choice may be to pick the 'best' technology (however it is defined) and build a single technology fleet of generation. However, utilities build a portfolio of generation technologies considering the uncertainties in capital costs, technology feasibility, fuel costs for each technology, and a range of other factors including regulatory uncertainty.

*Question 7.* Recently, we saw press reports that DOE may find that the total life cycle cost for implementing Yucca Mountain—without recycling—has increased to at least \$76 billion. What does this mean given the original BCG study's much more conservative estimates for the repository cost?

Answer. In the BCG study we assumed the repository lifecycle costs from the 2001 DOE study (US DOE—Analysis of the Total Life Cycle Cost of the Civilian Radioactive Waste Management Program—2001). We then represented the civilian portion of these costs (estimated at approximately 73% of total costs) in 2005 dollars. This resulted in total undiscounted lifecycle cost assumption for the repository of \$46B in 2005 dollars.

Applying similar adjustments to the updated repository cost estimates would imply a new lifecycle cost estimate of approximately \$55B in 2005 dollars. This represents a 20% increase in costs from previous estimates. This increase would close the economic gap between a repository solution and a recycling solution.

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#### RESPONSES OF DENNIS SPUREON TO QUESTIONS FROM SENATOR JEFF BINGAMAN

*Question 1.* It appears that the Department has shifted focus towards near term deployment of a fuel separations plant—does the Department support the use of spent fuel separations technologies that are variations of the Plutonium Uranium Extraction process called PUREX in the near-term?

Answer. The Department is looking at a range of processing alternatives, including aqueous and electrochemical separations, that are able to recycle spent fuel and recover a portion of the energy value to produce electricity. The aqueous processes, including UREX, are all variations of PUREX. However, the Department is not considering any alternative that results in the separation of pure plutonium, because

such alternatives do not support the GNEP goal to promote proliferation resistance here and abroad.

*Question 2.* Is the Department considering sending spent nuclear fuel from U.S. reactors to overseas reprocessing facilities?

Answer. The Department is examining a number of options for how best to transition to a closed fuel cycle in the United States given that a domestic recycling industry has not been developed in the U.S. No decision has been made on the approach the United States would take to transition to a closed fuel cycle. The Department is currently preparing a Programmatic Environmental Impact Statement (PEIS) to analyze whether to transition to a closed fuel cycle. Analyses must be further informed by, among other considerations, the technical and supporting studies that are currently under development by industry through the Advanced Fuel Cycle Initiative, the domestic technology development and deployment component of the Global Nuclear Energy Partnership (GNEP), and are scheduled for submission to the Department later this fiscal year as part of the May 2007, Funding Opportunity Announcement.

*Question 3.* Is the DOE considering a government corporation to carry out the GNEP activities? If so how would it be funded?

Answer. The Department is currently examining how best to implement GNEP activities. The Department is considering a range of options, including establishing a government entity to manage all aspects of the back-end of the fuel cycle. The Secretarial decision in 2008 on the path forward for GNEP will be informed by, among other considerations, these analyses and input from industry teams currently examining best transition options to a closing the nuclear fuel cycle in the United States.

*Question 4.* If Mixed Oxide Fuel is used in the short term deployment scenario will it be sent to Yucca Mountain after use?

Answer. While the used MOX fuel could be sent to a geologic repository, we believe a more reasonable approach would be to store the used MOX fuel until successful development and deployment of advanced recycling and fuel fabrication technologies into suitable fuel and fast-spectrum burner recycling reactors that would be designed to consume the long-lived isotopes.

*Question 5.* In 1996 the National Academies estimated that it would require 1 fast reactor for every three light water reactors on order to consume their spent fuel or 33 fast reactors are required for just our existing fleet, does that assumption still hold true?

Answer. Conventional light water reactor fuels utilize a uranium-based matrix and the uranium in the fuel creates some additional transuranics (TRU) while some of the recycled TRU are being consumed. This effect is quantified by the conversion ratio (CR) which expresses how much TRU is produced to how much is consumed—thus the lower the CR, the greater the number of LWRs which can be supported by a given fast burner reactor. Fast reactors can be designed with a wide variability in CR; the range from 0.25 to 1.0 has been considered in GNEP fuel cycle studies. The lower limit of this range, CR=0.25, would support the 3:1 ratio statement. Since the CR impacts the fuel composition and performance of the fast burner reactor, we are now seeking industry input on the recommended CR for the burner reactor design. LWR recycle could also be used as an intermediate step for partial TRU destruction to reduce the required burner reactor fraction. We hope to be in a better position within the coming year to estimate achievable design characteristics of a burner reactor.

*Question 6.* Has the Department performed a mass balance of the GNEP reprocessed spent fuel in order to ascertain the new waste streams and storage needed? If so please provide the Committee with this data.

Answer. The Department is preparing a draft programmatic environmental impact statement (PEIS) that will include information on waste streams and characteristics from reprocessed spent fuel. The Draft PEIS is expected to be made publicly available in the near future for review and comment.

*Question 7.* Cooperative R&D on Pyroprocessing with South Korea. The DOE has encouraged South Korea". Korean Atomic Energy Research Institute to work with DOE national laboratories on pyroprocessing R&D. South Korea has a 1992 treaty with North Korea under which the two countries have agreed that neither will enrich uranium nor reprocess spent fuel. North Korea has violated this treaty but South Korea has said it won't in the hope that North Korea will come back into compliance. (North Korea recently agreed to have its reprocessing plant at Yongbyon disabled.) When the DOE has been asked whether its cooperative R&D program amounts to encouraging South Korea to violate its commitment not to reprocess, its response reportedly has been "pyroprocessing is not reprocessing." For the purpose of nonproliferation policy, reprocessing could be sensibly defined as separating plutonium from most or all the fission products with which it is mixed.

Pyroprocessing of spent fuel that is more than a few years old does, in fact produce a transuranic product that is pure enough that the gamma field associated fission products no longer is intense enough to satisfy the IAEA's definition of "self-protecting." (The gamma field around fifty-year-old spent fuel is ten times the intensity required for self-protection.) The radiation level around the product of pyroprocessing ten year-old spent fuel would be less than one percent of the self-protection level. What definition is the DOE using when it says that "pyroprocessing is not reprocessing?"

Answer. The Republic of Korea (ROK) has the sixth largest nuclear power program in the world. The Government of ROK has made a commitment not to possess reprocessing or enrichment facilities and is limiting the scope of its research and development on pyroprocessing, otherwise known as electrochemical processing, technologies. ROK is actively engaged in the development of advanced reactor and fuel cycle technology, nuclear safety, radioactive waste management, and other related work programs on the national, bilateral and multilateral levels. We gain a great deal of knowledge and experience by working with these ROK experts and involve them in GNEP research and development involving small-reactors, advanced burner reactors, computer modeling, safeguards and basic science, but not separations of spent fuel. Administration policy on pyrochemical processing cooperation with ROK is based on a careful evaluation of the specific circumstances. Decisions to pursue this cooperation took into consideration not only the nature of the technology but also the nonproliferation commitments and track record of ROK, including its commitment not to possess reprocessing and enrichment facilities, as well as its technical capabilities.

*Question 8. Purex vs. COEX.* You have declared repeatedly that whatever reprocessing technology DOE chooses will not separate out pure plutonium. AREVA reportedly has offered as a technology that would satisfy this criterion COEX which would leave the plutonium mixed with uranium at a level of at least the seven percent plutonium used in MOX fuel or the 20 percent level that would be used in fast-neutron reactor fuel. Critics point out, however, that pure plutonium could be separated out of such a mix in a glove box without shielding. If on a proliferation-resistance scale, one set the difficulty of separating plutonium out of spent fuel at one hundred and pure plutonium oxide separated by PUREX as zero, where would you locate the proliferation resistance of the mixed oxide mixture that would be produced by COEX?

Answer. Proliferation resistance cannot be quantified by a simple reference to the product of a separations process or a mixture prepared for recycle as a reactor fuel. However, consideration of the relative proliferation resistance of a particular fuel cycle process must distinguish between national proliferation risks (e.g., diversion of nuclear material or misuse of the facility by the host nation) and sub-national risks (e.g., theft of nuclear material by a terrorist group, radiological sabotage), and must take into account the full range of extrinsic factors (such as safeguards and international commitments) and intrinsic factors (such as the composition and accessibility of plutonium-bearing materials) that affect the degree to which one process makes proliferation more difficult to carry out relative to another process.

Lastly, the relative proliferation resistance of any spent fuel recycle approach must be considered in the broader context of the international fuel cycle architecture. A recycle facility in the United States that supported international fuel services would need to address subnational security risks, but would be a net gain for nonproliferation if it discouraged other countries from pursuing independent fuel cycles.

*Question 9. Reprocessing U.S. spent fuel in France.* A nuclear-industry newsletter reported last week that you are considering shipping the approximately 3,000 tons of U.S. power reactor spent fuel stored at U.S. sites that do not have operating power reactors to France to be reprocessed. At \$500-2000 a kilogram, this would cost \$ 1.5-6 billion and 20-30 tons of plutonium would be separated. France's reprocessing contracts require that the plutonium and high-level waste be sent back to the customer nation. Two questions: i) What would DOE do with this additional separated plutonium? Pay France to make it into mixed oxide fuel and pay a U.S. utility to irradiate it as DOE plans to do with the most of 54 tons of its own plutonium that it has declared excess? ii) Where will it store the high-level waste? If there is a DOE site willing to store high-level waste from reprocessing spent fuel in France, would it not be much easier and less costly and more secure (in not exposing more separated plutonium to possible theft) to simply store the unprocessed spent fuel at that site?

Answer. At this time, the Department is not considering shipping used nuclear fuel to France or any other country for reprocessing. Should the Department con-

sider sending used nuclear fuel overseas for reprocessing in the future, the questions posed and other appropriate considerations would be carefully addressed.

*Question 10.* Since GNEP was launched, South Africa has announced it is considering reviving a former uranium enrichment program, while Argentina, Canada and Australia have suggested they might start their own as well. Eight countries have notified the International Atomic Energy Agency that they reserve the right to pursue enrichment and reprocessing technologies.

Yet GNEP was envisioned and sold as a way to stop the spread of enrichment and reprocessing technologies. In fact, it seems to be doing just the opposite, undermining decades of work the United States has done to discourage other countries from pursuing these technologies. How do you respond to this criticism?

Answer. The policy of the United States is to discourage the spread of enrichment and reprocessing technologies. In his February 2004 speech at the National Defense University, President Bush called for steps by suppliers to halt that spread. The Global Nuclear Energy Partnership (GNEP), through its reliable fuel services initiative, would provide countries that might otherwise consider developing their own indigenous enrichment and recycling capability with a viable and less expensive alternative.

GNEP is one of several efforts by the United States and others to discourage the spread of enrichment and reprocessing technologies. This is particularly important now as nuclear power is increasingly being used worldwide to meet the growing demand for energy and enrichment services. In that context, it is natural for countries to consider entering the enrichment market both as a business opportunity and to address energy security concerns. The GNEP fuel services concept would seek to provide countries with an attractive and reliable alternative to developing their own enrichment or reprocessing capabilities. The fuel services concept is still being developed, and the role of countries that may supply fuel services remains to be defined. Further, since the business of uranium enrichment depends on economies of scale and faces significant technical barriers to market entry, the economic case for individual countries to build expensive enrichment facilities may be difficult to support.

*Question 11.* GNEP originally envisioned engineering-scale reprocessing facilities, and at different times a variety of reprocessing technologies (UREX, UREX+, UREX+ 1 a, etc) were proposed at various points, seemingly in response to criticisms that the proposals were not proliferation-resistant. The idea of mixed oxide (MOX) fuel in light water reactors was off the table. Then the proposal shifted to commercial-scale facilities. Now it seems that the new proposal calls for research and perhaps smaller facilities, without a plan for commercial scale facilities, and that MOX might be an option because of industry interest. Why should the Congress provide support for this program when the Department does not seem to have any ability to produce a consistent answer for what the program is?

Answer. The research and development component of GNEP, the Advanced Fuel Cycle Initiative (AFCI) program, has in fact evolved since GNEP was introduced in 2006. Since that time, we have sought input from our international partners, industry, the public, and from Congress. This input has proven valuable and has influenced the direction of AFCI. DOE continues to evaluate alternative nuclear fuel cycles that would improve waste management and reduce the risk of proliferation. This is a complex and important challenge that demands an objective evaluation of many alternatives. While the Department welcomes independent and critical scrutiny during the conceptual phase of this program, a range of reasonable alternatives must be evaluated as required under the National Environmental Policy Act as part of the public decision making process for major federal actions that significantly affect the environment. As a result, the AFCI range of analysis includes the consideration of technologies developed in our national laboratories as well as the application of more mature technologies. The benefits to the U.S. taxpayer of any large-scale application of nuclear fuel recycling technology will be weighed against the acceptability of cost and safety risks and the support of industry (both utilities and technology vendors) measured by the potential for private investment. The technology development aspect of AFCI will not be narrowed until the Secretary of Energy decides on the path forward in 2008, as the program has intended since its inception.

*Question 12.* At the September international GNEP meeting, sixteen countries signed on to a statement of principles which included that principle that countries joining GNEP "would not give up any rights." Secretary Bodman made a statement to the same effect. But the primary purpose of GNEP was to do exactly that, to get countries to renounce the pursuit of enrichment and reprocessing technologies. This proposal seems to have shifted dramatically from its initial vision. Please explain,

aside from attempting to promote nuclear power, what the Department is attempting to gain from GNEP if not limit the spread of dangerous technologies.

Answer. The policy of the United States remains to strongly discourage the spread of enrichment and reprocessing technologies. The Global Nuclear Energy Partnership (GNEP), through its reliable fuel services element, is one initiative to support that policy. By providing countries with a viable and less expensive alternative to developing their own costly enrichment and recycling capabilities, GNEP would offer this economic incentive for countries to refrain from enrichment and reprocessing without asking them to give up their rights. The Non-Proliferation Treaty (NPT) recognizes a right to peaceful uses of nuclear energy, in conformity with the non-proliferation obligations of the Treaty. Rather than asking countries to forego rights they see as inherent in the NPT, GNEP seeks to persuade them that other more economic avenues exist to exercising those rights.

*Question 13.* A group of 27 nuclear experts from diverse backgrounds in the Nuclear Power Joint Fact Finding (NJFF) Keystone report concluded that the GNEP program was not cost-effective, that it can create a significant proliferation risk and that it would not manage nuclear waste successfully. According to the report, "While reprocessing decreases the volume of high-level waste, the volume of low-, and intermediate-level wastes substantially increases." If there is MORE nuclear waste produced as a result of reprocessing, what is the point of pursuing the program?

Answer. If nuclear power remains a vital part of the nation's energy supply throughout this century, the continued use of the once-through fuel cycle would require multiple repositories. Recycling offers the potential for reducing the number of geologic repositories for spent fuel and high level waste that are needed relative to the once-through fuel cycle, which is a key benefit of GNEP. Disposing of spent nuclear fuel and high level waste is much more challenging and costly than disposing of low level waste. Accumulation of spent nuclear fuel in the United States will exceed the statutory capacity limit of the proposed Yucca Mountain repository in approximately three years, although the repository will likely not be available for spent fuel disposal for approximately 10 years. The Department of Energy estimates that the U.S. Government's liability from not accepting commercial spent nuclear fuel could be as high as \$7 billion if the Yucca Mountain repository opens in 2017, and this liability could continue to grow by an average of \$500 million for each year that the opening of the Yucca Mountain repository is delayed past 2017. The American taxpayers will bear these costs. To postpone the need for building significant additional repository capacity in the future to accommodate projected future discharges of spent nuclear fuel, establishing a domestic capability to recycle the spent nuclear fuel from at least a portion of the U.S. fleet of reactors could prove prudent in the long-term. The Department of Energy has engaged industry in studies to more fully evaluate requirements and approaches in this regard.

The U.S. operates the largest fleet of commercial nuclear power reactors in the world. Other countries with significant nuclear power programs have capabilities for recycling nuclear spent nuclear fuel (France, United Kingdom, Russia, and Japan). Establishing a recycling capability in the United States could provide a future option for dealing with domestic spent nuclear fuel, while enhancing the nation's ability to promote policies favorable to non-proliferation, and increase the possibility of spent nuclear fuel take-back from other countries in the future.

*Question 14.* Independent reports from nuclear energy experts (Keystone, Harvard, and the National Academies of Sciences) have all criticized GNEP for its technological immaturity. The NAS report calls on Congress to scale back the program, not invest more money into GNEP. What are some of the risks of proceeding with GNEP at an accelerated rate? What would be the impact of a failed reprocessing system on the nuclear utilities economy? Is there a risk of discrediting the nuclear industry or creating more waste sites like West Valley, New York?

Answer. Deployment on a commercial-scale of GNEP advanced technologies for separations and fast reactors that are not mature would entail many risks. No final decision has been made on which technology will be deployed or how. While many different options will be considered, any near-term deployment would use the best available proven technologies modeled after the technologies of other nations.

*Question 15.* As the Department of Energy has been promoting GNEP and reprocessing internationally and with industry, have any utilities and has any country committed to investing in reprocessing and fast reactor technology?

Answer. There are a number of utilities that have expressed interest in the GNEP program. Several countries currently reprocess spent nuclear fuel. There is interest in the United States in recycling used fuel and developing fast reactor technology. The Department is working with several industry teams that responded to our May 2007 Funding Opportunity Announcement to determine effective ways to achieve the goals of the GNEP program. In January 2008, four industry teams are sched-

uled to submit preliminary technical and supporting studies that include business plans informing the Department on matters such as potential facility costs, potential revenue from selling products (such as uranium, fuel, electricity) and costs that would need to be supported by government.

*Question 16.* How does DOE envision a public/private cost sharing arrangement? How much of the expense will be borne by the private sector?

Answer. DOE does envision public/private cost sharing but it has not determined the form this arrangement could take. DOE has engaged with industry through cooperative agreements in part to elicit the private perspective on how such an arrangement might be structured.

As the Department evaluates the appropriate technological path for the Advanced Fuel Cycle Initiative, the technology development component of the Global Nuclear Energy Partnership, one of the factors that will be considered is the expected contribution from private partners.

*Question 17.* Has the DOE done a cost analysis comparing the cost of reprocessing and transmutation with the cost of dry-cask storage as an interim solution? A17. DOE has not conducted an analysis that specifically evaluates the cost of reprocessing and transmutation versus the cost of dry-cask interim storage. The Advanced Fuel Cycle Initiative, the technology development component of the Global Nuclear Energy Partnership (GNEP), has been working with four industry teams through its industry engagement effort in conjunction with the May 2007 Funding Opportunity Announcement to better assess the costs of the reprocessing and transmutation strategies.

*Question 18.* What are the lifecycle cost estimates of reprocessing and transmutation [DOE has not publicly release any cost study since it pulled its cost numbers in 1999]? How does the cost compare with dry-cask storage and a permanent geological repository?

Answer. Through the Advanced Fuel Cycle Initiative, the technology development component of the Global Nuclear Energy Partnership (GNEP), the Department has engaged with industry through cooperative agreements to generate the pre-conceptual designs that would provide a basis for making these lifecycle cost estimates. The lifecycle costs for recycling with transmutation will depend significantly on the technologies being employed along with the business arrangements that will govern the transactions. The industry consortia are expected to provide information and insights into these issues. The expected costs of technologies will be a factor in whether or not they will be used.

A comparison of recycling against a once-through approach depends on the assumptions concerning the number of geologic repositories needed. Under current law, the amount of material that can be placed in the Yucca Mountain repository is limited to 70,000 metric tons until a second repository is operating (even though the actual capacity of the Yucca Mountain repository can reasonably be expected to be several times larger than the statutory limit of 70,000 metric tons). If the assumption is made that the capacity of repositories will be limited to 70,000 metric tons, then the costs of identifying, siting licensing and constructing additional geological repositories will be substantial.

*Question 19.* Much of the space in a permanent geologic repository save through its implementation of GNEP relies on storing strontium and cesium above ground. Where will these fission products be stored and for how long?

Answer. DOE is currently evaluating various approaches to cesium/strontium (Cs/Sr) waste forms and storage. The draft GNEP Programmatic Environmental Impact Statement is examining a range of reasonable alternatives for disposition of Cs/Sr, including above-ground storage for approximately 300 years and disposal of the Cs/Sr as HLW in a geologic repository.

*Question 20.* At the latest GNEP Ministerial, DOE stated that France and Japan would not be required to stop extracting pure plutonium [Japan re-mixes the Pu with Uranium]. Isn't there a significant risk that this move away from the proliferation-resistance goal of GNEP is legitimizing France and Japan's dangerous example of separating out pure Pu and stockpiling this weapons-grade material? Where the implications for U.S. and international nuclear non-proliferation efforts?

Answer. The GNEP Statement of Principles state that the goals of GNEP are to "develop and demonstrate, inter alia, advanced technologies for recycling spent nuclear fuel for deployment in facilities that do not separate pure plutonium with the long term goal of ceasing separation of plutonium and eventually eliminating stocks of separated plutonium." (Emphasis added.) By signing this document, the seventeen partners, including those now engaged in reprocessing, will work toward the goal of recycling spent fuel without separation of pure plutonium and eliminate stocks of separated plutonium. The United States and its partners support improving the proliferation-resistance of new processes and new fuels. In fact, a primary



goal of the advanced research and development activities within the partnership is to develop these technologies and processes. Until such time as the technologies are available, France and Japan are maintaining their capabilities as part of their national energy and waste management policies. By agreeing in the Statement of Principles to “take advantage of the best available fuel cycle approaches,” they have committed to the goal of utilizing improved technologies once they become available. GNEP therefore strengthens our ability to improve nonproliferation practices in those countries and ratifies the intent of the partners to do so.

*Question 21/22.* In a November 7 Energy Daily article, it was reported that DOE “is planning to ask Congress for authority to take title to spent nuclear fuel stockpiled at closed U.S. nuclear plants and to reprocess it, most likely in France.” I am extremely concerned about the financial cost, proliferation and contamination risk of shipping US nuclear waste and plutonium across the Atlantic. Many countries, including Germany, Switzerland and others have stopped reprocessing their waste in France, in part because nuclear waste from reprocessing was being shipped back to these countries in addition to the plutonium, negating their hope to reduce the amount of radioactive waste they need to address. In fact, France is looking for a site to dispose of its high-level nuclear waste generated from its reprocessing program. If the waste from reprocessed US waste is shipped back, what benefit is there to shipping US waste to be reprocessed abroad, given the cost, proliferation risks?

Answer. At this time, the Department is not considering shipping used nuclear fuel to France or any other country for reprocessing. Should the Department consider sending used nuclear fuel overseas for reprocessing in the future, the question posed and other appropriate considerations would be carefully addressed.

*Question 23.* How does shipping US nuclear waste to France meet any of the goals initially put forth by GNEP?

Answer. At this time, the Department is not considering shipping used nuclear fuel to France or any other country for reprocessing. Should the Department consider sending used nuclear fuel overseas for reprocessing in the future, the question posed and other appropriate considerations would be carefully addressed.

*Question 24.* France has not solved its nuclear waste problem and is losing its foreign customers, and the U.K. is planning to permanently shut down its reprocessing Facility (the facility has been shut down indefinitely since 2005 after a massive radioactive leak was discovered). Are there any lessons to be learned from the French and U.K. experience?

Answer. DOE has a long history of working with international partners to leverage their knowledge and provide the maximum benefit for the U.S. investment. France has a successful recycling program, and is working on advanced technologies to further benefit their recycling program. The UK has not yet made a decision on the future of its nuclear program; a decision is expected early next year. Japan is about to start operation of a new recycling facility with state of the art safeguards. A decision to construct and deploy recycling facilities in the U.S. would consider the market readiness for such facilities. The international nature of the GNEP program enables leveraging international knowledge and lessons learned. Any decision on GNEP would be based on a sound and sustainable business model.

*Question 25.* DOE has changed its reprocessing plan pursuant to GNEP at least four times. DOE has proposed separating out (1) plutonium and neptunium, (2) plutonium and un-separated transuranics, (3) plutonium and americium and curium and lanthanides, and (4) now DOE proposes to separate plutonium with uranium (COEX process). What is DOE’s plan?

Answer. There are many paths to achieving a used nuclear fuel recycling program in the United States. All of those alternatives listed in this question, as well as others, are appropriate for consideration as the Department provides the necessary analysis for the path forward for the Advanced Fuel Cycle Initiative, the technology development component of the Global Nuclear Energy Partnership (GNEP). It should be noted that a range of reasonable alternatives must be evaluated as required under the National Environmental Policy Act (NEPA) as part of the public decision making process for major federal actions that significantly affect the environment. The Department’s plan for a Secretarial Decision on the path forward in 2008, after completing the NEPA process, has remained constant throughout the program’s existence.

*Question 26.* According to Prof. Frank von Hippel’s report Managing Spent Fuel In The United States: The Illogic Of Reprocessing (Figure 7 of the report <http://www.fissilematerials.org/ipfm/sitedown/ipfmresearchreport03.pdf>), separating out plutonium with neptunium or uranium is not more self-protecting than pure plutonium despite DOE claims that these options would be more proliferation resistant. Will there be a requirement that the separated mix meet the IAEA self-protection standard (100 rems/hr/meter)? How hard would it be to chemically separate ura-

mium from plutonium to obtain pure plutonium for a nuclear weapon? How does this proliferation-resistance compare with the proliferation-resistance of our current practice of not reprocessing?

Answer. Arguments about the relative proliferation resistance of a particular nuclear fuel process, or its nuclear materials rest on many elements. These elements of proliferation resistance include both “extrinsic” measures such as international safeguards that address national proliferation, and physical protection and material control and accounting systems that address subnational risks and “intrinsic” factors such as barriers within the facility design that affect ease of access to nuclear materials or characteristics of the nuclear material that would complicate its use in a nuclear explosive device or weapon. The differences in technical capabilities of national and subnational proliferators must be taken into account in assessing the degree of difficulty intrinsic measures in particular pose.

The external dose rate associated with a given nuclear material form is one factor that affects proliferation resistance. However, the notion of “self-protection” is relevant primarily to subnational proliferation risks. A national proliferator, especially one capable of designing and operating a reprocessing plant, would possess the technical capability to work with highly radioactive materials. In light of the demonstrated willingness of terrorists to sacrifice their own lives to carry out their missions, careful consideration needs to be given to the level of external dose that would prevent a subnational group from obtaining access to material that could be used in a nuclear explosive device. The relative proliferation resistance of a given fuel cycle process or nuclear material cannot be reduced to a single factor such as the external dose rate. However, consideration of the relative proliferation resistance of a particular fuel cycle process must distinguish between national proliferation risks (e.g., diversion of nuclear material or misuse of the facility by the host nation) and sub-national risks (e.g., theft of nuclear material by a terrorist group, radiological sabotage), and must take into account the full range of extrinsic factors (such as safeguards and international commitments) and intrinsic factors (such as the composition and accessibility of plutonium-bearing materials) that affect the degree to which one process makes proliferation more difficult to carry out relative to another process.

Lastly, the relative proliferation resistance of any spent fuel recycle approach must be considered in the broader context of the international fuel cycle architecture. A recycle facility in the United States that supported international fuel services would need to address subnational security risks, but would be a net gain for nonproliferation if it discouraged other countries from pursuing independent fuel cycles.

It is relatively easy, particularly for a state-sponsored proliferator to separate uranium from plutonium. This is why GNEP aims to prevent the further spread of reprocessing capabilities.

*Question 27.* Have any countries, including the 16 countries that signed up as GNEP partners at the second GNEP Ministerial, committed to forego developing or acquiring uranium enrichment and/or plutonium reprocessing?

Answer. With the signing of the Statement of Principles, the eleven new partners indicated their support for reliable fuel services as a viable alternative to enrichment and reprocessing. There are other countries that have expressed interest in joining GNEP, and would be like-minded in their support of reliable fuel services. Since the reliable fuel services envisioned by GNEP have not yet been established, no country has yet made any commitments based on the availability of those services.

*Question 28.* If fast reactors will not be commercially-viable for several decades at best, what is the urgency to proceed with reprocessing now? Please comment on the proliferation and costs risks of proceeding now rather than waiting until the technology is more mature or until uranium prices are high enough to justify this costly and dangerous program.

Answer. The Department is currently collecting information to support a Secretarial decision in 2008 on the path forward for the domestic development of GNEP, through the Advanced Fuel Cycle Initiative (AFCI). The forecasted growth in electricity demand, coupled with the concern about increased greenhouse gas emissions in the United States, make nuclear power a viable option that can help solve these challenges. The Administration believes that in the long term, closing the fuel cycle is the best approach to developing a comprehensive and economical waste management strategy to support the potential expansion of the number of reactors and resultant used fuel in the United States. However, transitioning from a once-through fuel cycle to a closed fuel cycle in the U.S. would take years to complete. One possible approach would be to begin today with existing technology, which would avoid

separation of pure plutonium, and later, introduce advanced recycling technologies into these facilities as those technologies mature.

The decision on whether to proceed with advanced recycling technologies and close the fuel cycle has not yet been made. This decision is anticipated to be made in 2008, based on completion of a Programmatic Environmental Impact Statement (PEIS) for GNEP, input from industry through its cooperative agreements resulting from the May 2007 Funding Opportunity Announcement, Departmental analyses, and other factors.

*Question 29.* DOE has recently explained that any near-term construction of a fast reactor and a reprocessing facility would be done by industry. By your estimate, and from what you have learned from industry, how much would you expect industry to contribute to the cost of building the first fast reactor? For the first reprocessing plant? DOE's Notification for the Programmatic Environmental Impact Statement included a range of capacities and throughputs listed for the advanced fast reactor—250 MW/thermal up to 2,000 MW/thermal—and for the reprocessing plant—100 metric tons of heavy metal annually up to 3,000 metric tons of heavy metal annually. What are the estimated costs to build these facilities, at the high and low range?

*Answer.* The Department has solicited technical and business data from industry as part of the May 2007 Funding Opportunity Announcement to evaluate the various options available to design and construct fast reactor and reprocessing facilities. We expect to receive this data in January and April 2008, and it will be used to develop cost and schedule information for various options. The results of these analyses, as well as the Programmatic Environmental Impact Statement (PEIS), a non-proliferation impact analysis, and other factors will be considered to provide information to the Secretary on a path forward for advanced recycling technologies. The Department anticipates that the marketplace will enable the commercial sector to provide a substantial share of the costs.

*Question 30.* DOE has often said that it needs to proceed now with design and construction of a reprocessing facility, even if it uses separation technology less advanced than the GNEP UREX process, because the U.S. needs to be "part of the game" and "have a team on the field." In essence, DOE implies that the U.S. needs a reprocessing facility to play a leadership role in influencing future choices regarding nuclear energy technology. How would building a reprocessing facility that uses existing technology or minor variations on existing technology help the U.S. influence other countries' technology choices?

*Answer.* The Department has made no recycling technology selections at this time and, in accordance with the National Environmental Policy Act, DOE is currently evaluating alternative technologies and approaches to closing the nuclear fuel cycle. The Department has engaged industry to examine ways to best introduce a closed fuel cycle in the United States. Through this process, industry is currently conducting conceptual design studies, developing technology roadmaps, and preparing business and communication plans for technology proposals. As part of this effort, the Department will receive input on how existing technologies could transition to advanced technologies with additional used fuel partitioning capabilities and with greater reductions in the toxicity and volume of high level waste. In addition, DOE is seeking input from industry to help determine whether there is a business case for constructing a fuel recycling facility using readily available processes that do not separate pure plutonium.

*Question 31.* DOE has indicated that the Secretary of Energy will decide on the "path forward" for GNEP in June 2008. Which specific issues will the Secretary decide and what criteria will he use?

*Answer.* There are several potential decisions that could be made through a NEPA Record of Decision (ROD). The first is a domestic programmatic decision whether to pursue an alternative to the open fuel cycle, and if so, some definition of potential implementation steps. Another potential decision involves whether to site, construct, and operate an Advanced Fuel Cycle Facility (AFCF), a research and development facility, and if so, whether to construct a new facility or facilities at one or more locations, or whether to modify one or more existing facilities. Criteria used in these decisions would include consideration of the potential environmental impacts, reduction in proliferation risk, technical considerations/technology maturity, estimated lifecycle cost, the business case, and legal and policy matters.

*Question 32.* GNEP has many ambitious goals and objectives, and it seems unlikely that the department will be able to maximize all of them at once. Could you state for this committee what GNEP's goals and objectives are, in what order of priority?

*Answer.* GNEP is a multifaceted effort that largely consists of two components: international and domestic. Internationally, GNEP is an international partnership, consisting of 21 nations, that seeks to promote a significant, wide-scale use of nu-

clear energy in a safe and secure manner, and to take actions now that will allow that vision to be achieved while decreasing the risk of nuclear weapons proliferation and effectively addressing the challenge of nuclear waste disposal. Domestically, through DOE's Advanced Fuel Cycle Initiative (AFCI), GNEP is focused on evaluating ways to effectively close the nuclear fuel cycle by advancing research and development and industry cooperation to foster advanced recycling technologies that are more proliferation resistant and reduce the volume and radiotoxicity of the nuclear waste that ultimately requires disposal in a geologic repository. GNEP was created to realize these goals and to ensure the United States is not only a participant in international discussions concerning the expansion of nuclear energy, but that it regains its role as a nuclear energy leader.

Both components of GNEP are equally important and are essential to the necessary expansion of nuclear power in the United States and worldwide.

*Question 33.* DOE has recently begun working with industry partners on conceptual design studies for a reprocessing facility and a fast reactor while DOE's national labs continue to work on the advanced technology needed to meet GNEP objectives—most of this advanced technology has thus far has only been demonstrated at the laboratory scale.

In light of the time and expense needed to demonstrate the advanced technologies that are intended to maximize GNEP goals, what is the rationale of DOE's intent to proceed with an accelerated schedule for design and construction of a reprocessing facility and fast reactor using less advanced technologies that would only partially meet GNEP objectives?

Answer. The Department has not made a decision to proceed with design and construction of a reprocessing facility or fast reactor. The Department has engaged industry to examine ways to best introduce a closed fuel cycle in the United States. Through this process, industry is currently conducting conceptual design studies, developing technology roadmaps, and preparing business and communication plans for technology proposals. As part of this effort, the Department will receive input on how existing technologies could transition to advanced technologies with additional used fuel partitioning capabilities and with greater reductions in the toxicity and volume of high level waste. These analyses will help inform a Secretarial decision in 2008 on the path forward for advanced recycling technologies.

Implementing an interim step using mature recycling technology which does not separate pure plutonium could support GNEP goals: recovery of reusable fuel resources and subsequent generation of electricity, strengthen the nonproliferation regime by supporting reliable fuel services, and improved waste management in which the volume of waste is reduced with the removal of uranium and plutonium.

*Question 34.* Unlike other countries that have continued reprocessing spent fuel, the U.S. has the opportunity to begin with a relatively clean slate, using advanced technologies. Yet DOE's funding opportunity announcement states that DOE is willing to consider "incremental approaches that meet the GNEP vision in a stepwise fashion." That seems to be a roundabout way of saying that the department will consider building facilities—very expensive facilities—which it knows from the outset won't meet GNEP's objectives. Why would the United States take this approach and risk locking ourselves in to technologies that won't meet our needs?

Answer. The Department is currently evaluating a variety of options available to realize the goals and objectives of the Advanced Fuel Cycle Initiative, the domestic technology development component of GNEP. One option is to implement a phased approach that would start with current commercially available technologies and processes that recover a significant percentage of the energy value of used nuclear fuel by recycling uranium and plutonium for re-use in existing nuclear reactors. Implementing an interim step using mature recycling technology could offer benefits in support of GNEP goals: recovery of reusable fuel resources and subsequent generation of electricity, strengthen the nonproliferation regime by supporting reliable fuel services, and improved nuclear waste management in which the volume of waste is reduced with the removal of uranium and plutonium.

The continued development of additional partitioning technologies would support the deployment of advanced recycling facilities that would recover additional energy value of the fuel for use in fast reactors and achieve the full waste management benefit. However, transitioning from a once-through fuel cycle to a closed fuel cycle in the U.S. will take years to complete.

The decision on whether to proceed with advanced recycling technologies and close the fuel cycle has not yet been made. This decision is anticipated to be made 2008, based on a Programmatic Environmental Impact Statement, which will include input from the public and industry, as well as Departmental analyses, and other factors.

*Question 35.* It has come to the attention of this committee that DOE is considering production of mixed-oxide (MOX) fuel for burning in existing reactors under GNEP. However, MOX recycling actually increases inventories of americium and curium—two of the elements that the department has said should be kept out of a geologic repository, if possible, in order to extend its capacity. MOX recycling also increases the total inventory of plutonium in circulation outside the repository, compared to a once-through fuel cycle. Please explain the rationale for considering a MOX program as part of GNEP.

*Answer.* Consideration of incorporating MOX burning in existing reactors is driven by the deployment benefit which derives from the fact that, although a MOX thermal recycle would “actually increase inventories of americium and curium,” it could reduce the quantity of plutonium by both burning it in MOX fuel and avoiding generation of new plutonium from enriched uranium Light Water Reactor (LWR) fuel. This approach could mitigate the net accumulation of transuranics in LWR spent fuel, allowing fast burner reactors to be deployed in a more gradual manner than if transuranic elements from light water reactor used fuel were sent directly to fast burner reactors.

While there might be “more plutonium outside the repository, compared to a once-through fuel cycle,” the plutonium would be fully removed from the waste stream and used instead to produce electricity, thereby contributing to the economy while reducing overall greenhouse gas emissions from electricity production.

The decision on whether to proceed with advanced recycling technologies and close the fuel cycle has not yet been made. This decision is anticipated to be made in 2008, based on a Programmatic Environmental Impact Statement, input from industry, Departmental analyses, and other factors.

*Question 36.* The U.S. stopped reprocessing in the late 1970s primarily due to proliferation concerns. GNEP proposes to develop advanced safeguards to address the basic GNEP goal of preventing diversion or theft of plutonium. The Advanced Fuel Cycle Facility, which is to serve in part as the testbed for developing advanced safeguards, is scheduled for completion in the 2020 timeframe, but this is the same timeframe envisioned for completing construction of the first reprocessing facility. What is the rationale for pursuing design and construction of a reprocessing facility prior to developing and demonstrating advanced safeguards?

*Answer.* One of the key conditions to establishing a used fuel recycling facility in the United States is the inclusion of advanced, state-of-the-art safeguards technology in its design. The core of this technology is available today and has been incorporated, with the expertise of our national laboratories, in the Rokkasho plant in Japan. Under GNEP, the Department does not intend to rest on today’s technology. With the Advanced Fuel Cycle Facility (AFCF), the Department plans to continue the advancement of all fuel recycling technology, including safeguards technology, to improve efficiency and effectiveness. Developing and demonstrating advancements in these technologies is an important element of GNEP. The safeguards improvements may be introduced, where feasible, to existing facilities world-wide and can be incorporated by design in future facilities in the United States and elsewhere.

*Question 37.* GNEP prohibits reprocessing spent fuel in a way that separates out pure plutonium. GNEP’s UREX separation technologies are designed to keep the plutonium mixed with other highly-radioactive materials found in spent fuel, thereby making it more difficult to use for weapons production. The committee has learned that DOE is now considering using less advanced technologies that result in a uranium plutonium mixture that is far less proliferation resistant than the mixture resulting from UREX technologies. What is the rationale for using this less advanced technology?

*Answer.* The Department is currently evaluating a variety of options available to realize the goals and objectives of the Advanced Fuel Cycle Initiative, the domestic technology development component of GNEP. One option is to implement a phased approach that would start with current commercially available technologies that recover a significant percentage of the energy value of used nuclear fuel by recycling uranium and plutonium in existing nuclear reactors.

Implementing an interim step using mature recycling technology could offer benefits in support of goals established in the GNEP Statement of Principles: recovery of reusable fuel resources and subsequent generation of electricity, strengthen the nonproliferation regime by supporting reliable fuel services, and improved nuclear waste management in which the volume of waste is reduced with the removal of uranium and plutonium.

The continued development of additional partitioning technologies would support the deployment of advanced recycling facilities that would recover additional energy value of the fuel for use in fast reactors and achieve the full waste management

benefit. However, transitioning from a once-through fuel cycle to a closed fuel cycle in the U.S. will take years to complete.

The decision on whether to proceed with advanced recycling technologies and close the fuel cycle has not yet been made. This decision is anticipated to be made 2008, based on a Programmatic Environmental Impact Statement, which will include input from the public and industry, as well as Departmental analyses, and other factors.

*Question 38.* In support of developing GNEP facilities, your strategic plan states that if the U.S. is going to “participate in assuring access to nuclear fuel, and in the longer term, spent fuel services to [other countries], the U.S. must have the capability to provide the needed fuel cycle services” including “cradle to grave” fuel service or leasing arrangements. Yet the United States could accomplish the first goal—helping assure access to nuclear fuel—without building any GNEP facilities, for example by participating in an international fuel bank. As far as the second goal, we have to consider the question of plausibility.

How likely is it that the American people will agree to reprocess spent fuel from other nations and accept all the attendant risks associated with transportation of that fuel and operation of the plant—and what would be done with the waste?

Answer. Public acceptance would be important for any proposal to accept and recycle spent fuel from other countries. Public support for nuclear power has grown significantly, given the strong safety performance of U.S. reactors and growing concern over the environmental impact of fossil fuel use. The ability to recycle the spent fuel and reducing the volume of the resulting waste will be a key factor in public acceptance of such a proposal. In addition, the public would enjoy the security benefits of discouraging other countries from developing fuel cycle capabilities that could readily be misused for weapons purposes.

#### QUESTION FROM SENATOR DOMENICI

*Question 1.* Given all the political obstacles, escalating cost estimates and finite capacity of Yucca Mountain, and the growing DOE liability for failure to take possession of spent fuel, what do you think is the right U.S. waste management strategy going forward?

Answer. To help reduce the volume of waste that needs to be disposed of at Yucca Mountain, conserve resources and make the long-term expansion of nuclear energy a reality, the Department of Energy is assessing near term capability of closing the nuclear fuel cycle through a host of options and by working with industry to explore concepts and technologies to meet the needs of nuclear power. Transitioning from a once-through fuel cycle to a closed fuel cycle in the United States will take time, but this is our goal. The recycling industry in the U.S. would be at an early stage of development and the technologies, though used in other countries for years, are not used in the United States.

GNEP seeks to promote the expansion of nuclear power to achieve environmental, economic, and energy security benefits in concert with reduction of used nuclear fuel volume destined for a geologic repository while simultaneously recovering energy content contained in the used fuel and making the world a safer place by providing reliable fuel assurance to countries that might otherwise develop enrichment and reprocessing capabilities. GNEP seeks to move the U.S. in this direction, while still addressing the core targets of reducing proliferation risks, and repository waste volume.

*Question 2.* Some are concerned that GNEP is rushing to deploy technologies that are not yet ready. What recycling research and development technologies will be pursued under GNEP, and when?

Answer. Both advanced aqueous and electrochemical processing technologies have been pursued under the Advanced Fuel Cycle Initiative program, the domestic technology development component of GNEP, for the last decade, and the Department intends to continue the development of these advanced technologies. Completing the technology development will take at least another decade or longer. In addition, the Department has asked industry to identify what processes could be deployed in the near term with minimal technical risk. The schedule on which these processes could be deployed would depend on a variety of factors including the technical maturity and successful demonstration of the technologies, the readiness of the market to accept such technologies, and a sound and commercially sustainable business plan.

The Department is currently evaluating the option to include thermal recycle in existing LWR's to achieve goals established in the GNEP Statement of Principles. Under this approach, the development and deployment of technologies would be organized in two phases to obtain the full GNEP benefits. The first phase would rely on using incremental improvements of existing recycling technologies to reduce the

growth in the stockpile of spent nuclear fuel. It would focus on separations technologies that do not extract pure plutonium and provide a mix of uranium and plutonium for fabricating plutonium-bearing fuel for use in existing reactors. The spent plutonium-bearing fuel would be stored for future recycling through the use of advanced technologies. The use of existing technologies would provide an initial approach to address GNEP goals, and would enable sufficient time to develop the more advanced technologies to fully address these goals.

Under this scenario, the second phase would rely on the technologies that are currently being researched within the AFCI program: separations technologies that allow for a detailed management of all waste streams, and advanced fuels and reactors that would allow for the transmutation of key transuranic elements. The implementation of these technologies would start in 20 to 25 years.

*Question 3.* My understanding is that the implementation of GNEP will be flexible, that it will be done in a way that utilizes the best available technology. As developments occur, how will they be integrated over time?

Answer. GNEP is not a static vision, and its related policies and technologies are capable of evolving to meet the ultimate goals of the United States. Since the introduction of GNEP in 2006, we have pursued an aggressive path of seeking input and collaboration in many venues. In the design of any near-term separations facility, provision will be made for the addition of future improvement features. For example, remote maintenance of such plants would incorporate features that could be applied to upgrading the existing processes. The experience of the US government in the operation of large scale separations facilities for defense purposes has demonstrated such a capability repeatedly and successfully.

*Question 4.* If we want to limit the number of repositories that we ultimately need to the absolute minimum, don't we need to recycle spent fuel?

Answer. There are several factors that must be considered in the capacity and design of a geologic repository, with attention to three factors in particular: volume, heat load, and potential dose from radionuclides. Recycling does show promise in limiting the number of repositories but the extent to which it could accomplish this result varies.

The Nuclear Waste Policy Act (NWPA) requires the Secretary of Energy to inform Congress before 2010 on the need for a second repository for spent nuclear fuel (SNF). The NWPA also limits the capacity of the Yucca Mountain repository to 70,000 metric tons until a second repository begins operations. By 2010, SNF produced from current commercial reactors will be very near the statutory limit of 70,000 metric tons. Studies have shown significant reductions in the required amount of repository capacity can be achieved through SNF recycling. Also of importance is the type of repository under discussion. The 2004 Advanced Fuel Cycle Initiative Comparison Report to Congress analyzed the fuel cycle strategies of a once through system, thermal recycle, thermal plus fast recycle, and fast recycle, to determine impacts of the different fuel cycle systems on waste management indicators. The results of the comparison support the idea that the number of potential future repositories can best be limited with continuous recycle of transuranics from SNF, as envisioned by the long-term objectives of GNEP.

*Question 5.* The National Academy of Sciences, formed a committee to evaluate the Office of Nuclear Energy R&D program, including the GNEP initiative. While this report endorsed continued R&D of nuclear recycling technologies, it did not support the rapid deployment of commercial technology. What do you think of the conclusion of this report?

Answer. While we feel that some conclusions of the report are accurate, such as the high-priority the report places on the Nuclear Power 2010 program as well as the merit of closing the nuclear fuel cycle, we have significant disagreement with a number of conclusions of the report relating to GNEP.

As an initial matter, it is important to note that the National Research Council (Council) was solely reviewing and commenting on the Advanced Fuel Cycle Initiative (AFCI), the research and technology development component of the Global Nuclear Energy Partnership (GNEP), and not the international partnership component of GNEP, as evidenced by the press release that accompanied the issue of this report.

DOE believes that the AFCI program is fundamentally consistent with most of the recommendations that the Council reached in its Review of DOE's Nuclear Energy Research & Development Program. However, the conclusion of the report relating to GNEP is that the program "should not go forward and that it should be replaced by a less aggressive research program." We believe this conclusion is premised on the faulty assumption that DOE has narrowed the potential technology to be deployed solely to UREX+ (the baseline technology developed at DOE's National Laboratories) and that it is moving too aggressively towards commercial deployment.

However, as noted to the Council both via interview and in multiple documents, we have made no technology selection and in accordance with the National Environmental Policy Act are currently evaluating alternative technologies and approaches to the current open nuclear fuel cycle.

DOE agrees with the council that advanced recycling technologies that can separate all transuranic elements from spent nuclear fuel and subsequently fabricate them into fuel to be consumed in a fast reactor require additional research. The AFCI program continues to work on the research and development necessary to eventually bring these technologies to market.

Additionally, DOE strongly disagrees with the lack of urgency the Council places on efforts to deploy technologies that will close the nuclear fuel cycle and thereby support the necessary, robust expansion of nuclear power in the United States. It is projected that the United States will need to construct 45 new nuclear plants by 2030 merely to maintain nuclear energy's 20% share of electricity generation given the expected increase in demand. The United States must develop a waste management strategy that can facilitate such an expansion, and deployment of recycling technologies is integral to this strategy.

The Council made some recommendations that DOE agrees with. Specifically the Council recommended that DOE's technical efforts undergo an independent peer review. DOE's Idaho National Laboratory sponsored a review by an independent panel of 12 fuel-cycle experts that was published on November 2, 2007. This panel ultimately concluded that, "... GNEP is the right program for the United States to undertake at the right time."

*Question 6.* Dr. Bunn states in his testimony that he believes that the U.S. "emphasis on reprocessing" would allow non nuclear states to "gain in-depth experience in plutonium reprocessing and metallurgy." What do you think of this statement and do you believe that the GNEP program will lead to widespread dissemination of advanced recycling technologies?

Answer. To the contrary, GNEP aims to close the fuel cycle in a manner that reduces the overall proliferation risk in the international nuclear fuel cycle. By developing recycle technologies that minimize waste, GNEP would make it more feasible to offer reliable nuclear fuel services as a viable alternative for countries that might otherwise consider developing enrichment or reprocessing capabilities. This would support the President's policy of seeking to prevent the further spread of those sensitive nuclear fuel cycle technologies. All international cooperation under GNEP is subject to export control and technology transfer review to ensure that it does not contribute to the spread of sensitive technologies. Cooperation on sensitive technologies is taking place under bilateral arrangements with countries that already have such technology.

*Question 7.* What does the empirical evidence show with regard to the spread of recycling technologies as used by Great Britain, France, Russia and Japan versus the proliferation of enrichment technology?

Answer. The recycling technologies currently used by several foreign countries (the PUREX separations process) was developed in the United States and was later declassified and described in the open literature (see "Nuclear Chemical Engineering", Benedict and Pigford, McGraw-Hill Publishing Company, 1957). Although technological improvements have been made, the basic process has been well-known for fifty years. It was used by India to separate the plutonium used for its first atomic explosion (described by India as a peaceful detonation) on May 18, 1974. Recently, North Korea used plutonium recovered from spent nuclear fuel via the PUREX process to test its first weapon.

The technology associated with uranium enrichment is more complex and the relative ease with which uranium enrichment plants used to produce low enriched uranium for commercial nuclear power can be converted to weapons production with the right technologies is a concern. The A.Q. Khan network's proliferation of enrichment technologies to countries such as Libya and Iran has been widely publicized and is the most glaring example of the proliferation of enrichment technology.

*Question 8.* Please explain how the GNEP program will be used to address the spread of nuclear material and address growing inventories of spent nuclear fuel.

Answer. GNEP is intended to help limit the spread of enrichment and reprocessing technologies by offering reliable fuel services as a viable alternative for countries that might otherwise consider developing their own indigenous enrichment and reprocessing capability. By limiting the spread of these technologies, GNEP would limit the international spread of the capability to produce the most sensitive forms of nuclear material. Most of the countries that have relevant fuel cycle capabilities are partners or observers in GNEP, and the two countries that currently offer reprocessing services internationally—Russia and France—are partners. By offering fuel services that include assistance in the management and disposition of spent



fuel, GNEP would help countries manage and draw down their inventories of spent fuel. This in turn will reduce pressures for countries to pursue indigenous reprocessing capabilities to manage growing inventories of spent fuel.

*Question 9.* I understand that 16 nations have joined us in GNEP, and not just expressed support but actually signed on the dotted line. France, Russia, Japan, Australia, China....what are these states saying to you about the future of nuclear power?

Answer. At the September 16, 2007, GNEP Ministerial, all sixteen partners presented remarks about their joining the Partnership and its relevance to their nuclear energy policy. In the Statement of Principles, the Partners "share a vision of the necessity of the expansion of nuclear energy for peaceful purposes worldwide in a safe and secure manner." In their remarks they focused on several key points. Nuclear power offers a source of reliable energy to meet dramatically escalating energy needs in virtually every country, without greenhouse gas emissions. Safety, security and nonproliferation are prerequisites for nuclear power development, and improved proliferation resistance should be incorporated into future nuclear energy and fuel cycle systems. The IAEA has an essential role in each of these areas, including helping countries develop the capacity to meet these requirements. Waste management solutions must be developed that deal with used fuel in a more efficient manner consistent with our non-proliferation objectives, and the research and development must be conducted to find such solutions. Countries interested in nuclear energy development stressed that adding nuclear power to their energy mix will be an important source of urgently needed electricity or desalination to improve the standard of living and to mitigate the rising cost of fossil fuels and the emission of greenhouse gases.

*Question 10.* In his testimony Dr. Wallace noted the potential benefits of advanced simulation in assisting in the design of both the separations and fuel fabrication processes to be utilized in GNEP. Would this capability be useful in supporting your program?

Answer. A key part of the long term strategy of the Advanced Fuel Cycle Initiative, the domestic technology development component of GNEP, is to apply DOE's leadership in advanced simulation as developed under the National Nuclear Security Administration (NNSA) Advanced Simulation and Computing (ASC) program and the Office of Science Advanced Scientific Computing Research (ASCR) program. Science-based virtual design capabilities can improve the design process for each of the key components of an advanced nuclear fuel cycle system. These capabilities would benefit a separations facility where, due to extremely high radioactivity levels, design changes are difficult to implement after the system has operated and improve the process of qualifying new reactor fuel forms which currently can take up to 20 years and \$200 million to develop for each new fuel form. Advanced simulation capabilities could also extend to fast reactor designs, waste forms and repository analysis, the design of safeguards systems, and to improved seismic design of critical nuclear safety systems. In short, virtually every aspect of the nuclear fuel cycle including its safety, performance, cost, manufacturability, reliability, security and proliferation resistance could be improved through the design and analysis techniques made possible by advanced computing and simulation. This potential and the US leadership in advanced computing is internationally recognized. Our key international partners, such as Japan and France are expressly interested in working with us to develop these computational capabilities.

#### QUESTION FROM SENATOR WYDEN

*Question 1.* Earlier in 2007, DOE spent more than \$10 million to fund 11 detailed siting studies for the GNEP facilities, including Hanford. Those studies were to be used in the programmatic environmental impact statement (PEIS) process. When will the draft EIS be released? Will it rank the 11 sites, and will one or more sites be selected as a preferred alternative? What fuel treatment technologies and what advanced burner reactor technologies will be included in the draft PEIS and will specific technologies be identified as preferred alternatives?

In the Committee hearing, Mr. Spurgeon stated that DOE would not be making decisions on which reprocessing and reactor technologies GNEP would deploy any time soon and that the NAS panel misunderstood the schedule for making these decisions. When will these technology decisions be made?

Answer. The Draft Programmatic Environmental Impact Statement (PEIS) is under development and is anticipated to be issued in the near future. The draft PEIS will examine a range of technology alternatives, covering both near-term and long-term timeframes. The Department is not currently planning to identify a pre-

ferred site for locating recycling facilities. Technology selection is not anticipated until after the expected Secretarial decision in 2008.

*Question 2.* Please identify all studies and analyses developed by the GNEP program of the radioactive waste volumes and sources of the different fuel cycles being considered for the program, e.g. transuranic, low-level, greater-than-class-C, high-level. DOE is currently in violation of the Tri-Party compliance schedule for cleaning up radioactive and chemical contamination at Hanford. What impact would selection of Hanford as a GNEP reprocessing site have on waste volumes and clean-up schedules for the site?

*Answer.* The draft PEIS will contain the estimates of wastes generated under each of the alternatives being evaluated, including the no action alternative. Information included in the Draft PEIS was derived from a variety of sources, including the conceptual design studies developed to date under GNEP. Copies of those source and reference documents will be included in the Administrative Record supporting the PEIS. Primary report sources include the following: Waste Generation Forecast and Characterization Studies (WH-G-ESR-G-00051 and WH-G-ESR-G-00054) and AFCF NEPA Data Study Project No. 27989. Additional supporting studies and analyses are contained in further reports which will be included in the administrative record.

DOE believes that selecting Hanford as a site for a GNEP reprocessing facility would have no impact on the site's clean-up schedule. The Hanford clean-up is independent of the GNEP activity by NE.

A number of other studies can be found on our website under Congressional reports: <http://www.ne.doe.gov/publicInformation/nePICongressionalReports2.html>.

*Question 3.* Please identify all studies and analyses developed by the GNEP program of the security and proliferation risks of the different fuel cycles and the different candidate sites being considered for the program. How will the security and the proliferation risks of the different fuel cycles and the different candidate sites be dealt with in the PEIS?

*Answer.* An element of the purpose and need for this action by the Department includes supporting the expansion of domestic and international nuclear energy production while reducing the risks associated with nuclear proliferation. To meet its nonproliferation goals with regard to spent nuclear fuel recycling, DOE will only assess as reasonable alternatives those processes that do not separate pure plutonium. The PEIS will evaluate a range of reasonable alternatives that are responsive to this purpose and need. The PEIS will evaluate a set of design basis accidents as well as beyond design basis accidents for each of the alternatives.

The Department's National Nuclear Security Administration is preparing a non-proliferation impact assessment that will address the programmatic alternatives being evaluated in the PEIS and will help inform the Secretary's Record of Decision. This assessment will build on established evaluation methodologies, particularly the Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy Systems, developed by the Proliferation Resistance and Physical Protection Evaluation Methodology Expert Group of the Generation IV International Forum (Revision 5, dated November 2006, is available online at <http://www.gen4.org/Technology/horizontal/PRPPEM.pdf>). NNSA is refining and applying these methodologies to GNEP through the project on Proliferation Risk Reduction Assessment. The first report under that project is UREX/COEX Proliferation Risk Reduction Study, by Robert Bari, Brookhaven National Laboratory, Jor-Shan Choi, Lawrence Livermore National Laboratory, Jon Phillips, Pacific Northwest National Laboratory, Joseph Pilat, Los Alamos National Laboratory, Gary Rochau, Sandia National Laboratories, Roald Wigeland, Argonne National Laboratory, Kory Budlong, Sylvester, Los Alamos National Laboratory, March 13, 2007.

The conceptual design studies being developed for GNEP will include security and proliferation risk considerations in the alternatives studies and design process. Security and proliferation resistance are considerations that will be addressed through the design process for facilities and technologies, and factor into site selection. The design process under DOE O 413.3 also requires the development of a vulnerability assessment, beginning in the conceptual design stage, to assure adequate security considerations are included in the design. Site evaluation in the PEIS for the AFCF includes the potential impacts of design basis and beyond design basis accidents to workers, the public and the environment.

A site selection for the Consolidated Fuel Treatment Center and the Advanced Burner Reactor will not be made based on this GNEP PEIS. Further NEPA review would be required at a future point in time prior to any site selection for such facilities.

*Question 4.* Please identify all studies and analyses developed by the GNEP program of the economic costs and risks of the different fuel cycles being considered for the program.

*Answer.* A listing of recent economic analysis papers and reports based on work sponsored by the program is provided below:

- D. Shropshire, K. Williams, B. Boore, J.D. Smith, et. al., 2007, Advanced Fuel Cycle Cost Basis, INUEXT-07-12107, April 2007.
- D. Shropshire, K. Williams, J.D. Smith, B. Boore, 2006, Advanced Fuel Cycle Economic Sensitivity Analysis, INUEXT-06-11947, November 2006.
- D. Shropshire, 2007, A Documented Resource for Nuclear Fuel Cycle Cost Information, Transactions of the American Nuclear Society, Volume 96, June 24–28, 2007, Boston, MA, page 117.
- K. Williams, 2007, Fuel Cycle Economic Analysis Using an Excel Spreadsheet, Transactions of the American Nuclear Society, Volume 96, June 24–28, 2007, Boston, MA, page 119.
- V. Bhatt, J. Morton, A. Reisman, J. Lee, 2007, Assessing Market Deployment of GNEP Technologies, Transactions of the American Nuclear Society, Volume 96, June 24–28, 2007, Boston, MA, page 144.
- E. Schneider, K. Rankin, 2007, An Econometric Model of the Uranium Market, Transactions of the American Nuclear Society, Volume 96, June 24–28, 2007, Boston, MA, page 113.
- G. Rothwell, C. Braun, 2007, Cost and Market Structures in International Nuclear Fuel Cycles, Transactions of the American Nuclear Society, Volume 96, June 24–28, 2007, Boston, MA, page 146.
- A. Phillips, J. Jacobson, D. Shropshire, 2007, VISIO1V.ECON A Dynamic Model for Evaluating Nuclear Fuel Cycle Costs, Transactions of the American Nuclear Society, Volume 96, June 24–28, 2007, Boston, MA, page 121.
- D. Shropshire, J. Morton, 2007, Nuclear Power: Applications of Industrial Ecology, Transactions of the American Nuclear Society, Volume 96, June 24–28, 2007, Boston, MA, page 687.
- E. Hoffman, J. Smith, 2007, Economics of the Nth Advanced Burner Reactor, Transactions of the American Nuclear Society, Volume 96, June 24–28, 2007, Boston, MA, page 137.
- G. Rothwell, K. Williams, 2007, Costs of Developing and Commercializing the Advanced Recycle Reactor, Transactions of the American Nuclear Society, Volume 96, June 24–28, 2007, Boston, MA, page 135.
- D. Shropshire, K. Williams, J.D. Smith, B. Boore, 2006, Advanced Fuel Cycle Economic Sensitivity Analysis, Transactions of the American Nuclear Society, Volume 95, November 12–16, Albuquerque, NM, page 172.
- D. Shropshire, J. Chandler, 2006, Financing Strategies for a Nuclear Fuel Cycle Facility, 14th International Conference on Nuclear Engineering, ICONE14-89255, July 17–20, Miami, FL.

Copies provided to the Committee.

*Question 5.* To date, GNEP development has been financed from appropriated funds. What is the DOE's plan to financing development and construction of U.S. GNEP fuel cycle facilities? Will these continue to be financed from appropriated funds? Or will DOE turn to utility fees or other financing mechanism and when will that decision be made?

*Answer.* Through the Advanced Fuel Cycle Initiative, the domestic technology development component of GNEP, the Department is seeking input related to funding options for advanced fuel cycle facilities through technical and supporting studies currently being prepared as part of the May 2007 Funding Opportunities Announcement. Industry teams are preparing technology development roadmaps, business plans, and a communications strategy supporting the conceptual design studies in an effort to inform a Secretarial decision expected in 2008.



## APPENDIX II

### Additional Material Submitted for the Record

*December 13, 2007.*

Hon. JEFF BINGAMAN,  
*Chairman, Committee on Energy and Natural Resources, U.S. Senate, Washington, DC.*

Hon. PETE V. DOMENICI,  
*Ranking Member, Committee on Energy and Natural Resources, U.S. Senate, Washington, DC.*

DEAR CHAIRMAN BINGAMAN AND RANKING MEMBER DOMENICI: As the United States seeks to reduce our reliance on foreign sources of oil and reduce our greenhouse gas emissions, it is becoming increasingly clear that to meet our current and future energy demands we must ensure that we have a balanced portfolio of energy supplies including nuclear. Over the last 30 years the United States has reduced its nuclear technological base and our leadership position in the world. While Congress and the Administration have recently initiated a number of important programs to support the deployment of new nuclear generation capacity domestically, the Administration's Global Nuclear Energy Partnership (GNEP) can be pivotal in re-establishing our nation's leadership position domestically and abroad.

The GNEP program has become one of the most recognizable international efforts to address the global use of nuclear energy and limit the proliferation risks associated with the nuclear fuel cycle. The Administration has made major strides in bringing the international community together by concluding agreements with eighteen nations on a "Statement of Principles" that addresses the prospects of expanding the peaceful uses of nuclear energy including enhanced safeguards, international fuel service frameworks, and advanced technologies. These countries have come to the same conclusion: we face growing electricity demand concurrent with reducing greenhouse gas emissions to control climate change and a strong nuclear program is a key component to achieving that end.

In many respects we are at a critical juncture in demonstrating U.S. global leadership in nuclear energy advancements not only in developing new generation reactors but, in particular, deploying spent nuclear fuel burning and recycling technologies that reduce the waste disposal burden on the environment while recovering useable fuel material. Today, instead of taking action we continue to cede this leadership and promising world market role to countries that have continued their efforts to close the nuclear fuel cycle because of the United States decision to suspend its support for reprocessing in the late 1970's. A lack of commitment to this mission will translate into missed job opportunities for the industry and American workers to gain from the nuclear resurgence that is currently underway.

The companies involved in the GNEP program believe, contrary to the recent National Academy of Sciences report on the Nuclear Energy program, the essential technology to support the goals of GNEP exists. In fact, DOE has taken steps to engage the industry to ensure that the knowledge and expertise of the private sector is available to support the Secretary of Energy's June 2008 Record of Decision on closing the fuel cycle in the U.S. The industry focus will be to provide input and recommendations from the conceptual design studies, technology development roadmaps, business plans, and the communications strategy regarding a nuclear fuel recycling center and advanced recycling reactor. This effort will better define the scope, schedule, cost and business arrangement to determine if a commercial solution for closing the fuel cycle in the US is sustainable.

On behalf of each of our companies and partners, we urge you to support the GNEP program. Thank you very much for your consideration of this request.

Sincerely,

DOROTHY DAVIDSON,  
*VP NE & Science Programs, AREVA Federal Services LLC.*

JOHN WILCZYNSKI,  
*Executive VP, Energy Solutions, LLC.*

CHRIS MONETTA,  
*Senior Vice President, GE-Hitachi Nuclear Americas, LLC.*

RONNE FROMAN,  
*Senior Vice President, Management, Energy Group, General Atomics.*

#### STATEMENT OF THE NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES

##### SUMMARY

Growing energy demands, emerging concerns about the emissions of carbon dioxide from fossil fuel combustion, the increasing and volatile price for natural gas, and a sustained period of successful operation of the existing fleet of nuclear power plants have resulted in a renewal of interest in nuclear power in the United States. The Office of Nuclear Energy (NE) in the U.S. Department of Energy (DOE) is the main agent of the government's responsibility for advancing nuclear power. One consequence of the renewed interest in nuclear power for the NE mission has been rapid growth in the NE research budget: by nearly 70 percent from the \$193 million appropriated in FY 2003 to \$320 million in FY 2006.

In light of this growth, the FY 2006 President's Budget Request asked for funds to be set aside for the National Academy of Sciences to review the NE research programs and budget and to recommend priorities for those programs given the likelihood of constrained budget levels in the future (DOE, 2005). The programs to be evaluated were Nuclear Power 2010, the Generation IV reactor development program, the Nuclear Hydrogen Initiative, the Global Nuclear Energy Partnership (GNEP)/Advanced Fuel Cycle Initiative (AFCI), and the Idaho National Laboratory facilities program. The committee's evaluation of each is summarized below, along with its assessment of program priorities and oversight and its relevant recommendations.

All but two members of the committee concur in the assessments presented in this report, and their views are presented in Appendix A. In particular, all committee members agree that the GNEP program should not go forward and that it should be replaced by a less aggressive research program. The authors of Appendix A would "hold DOE R&D spending [on the less aggressive fuel cycle research program] to pre-2003 levels, before AFCI" and they believe that "DOE is the wrong agent for developing commercial technologies beyond the early laboratory stage."

Separately, three other committee members who do agree with all the recommendations in the report expressed a preference for an alternative to the technology preferred by GNEP. They describe this preference in Appendix B.

##### NUCLEAR POWER 2010

The Nuclear Power 2010 (NP 2010) program was established by DOE in 2002 to support the near-term deployment of new nuclear plants. NP 2010 is a joint government/industry 50/50 cost-shared effort with the following objectives:

- Identify sites for new near-term nuclear power plants and obtain early site permits (ESPs).

**Recommendation.**—DOE should expand NHI program interactions with industrial and international research organizations experienced in chemical processes and operating temperatures similar to those in thermochemical water splitting. NE should also broaden the hydrogen production system performance metrics beyond economics for example, it could use the Generation IV performance measures of economics, safety, and sustainability.

##### OTHER GENERATION IV NUCLEAR ENERGY SYSTEM PROGRAMS

The second major concept for development in the Generation IV program, the SFR, seems vague at this time and appears to involve selected studies of technology issues that are principally beneficial for commercialization rather than being explicitly linked to the long-term technology needs of nuclear energy. The committee is concerned that the Generation IV concept evaluation criteria for reactor develop-

ment adopted by the Generation IV Roadmap were not applied in the selection of the VHTR and SFR. The Generation IV R&D priorities have been shifting with minimum discussion of criteria and alternatives.

The program resources are barely adequate for basic studies related to NGNP and the VHTR design and entirely inadequate for exploring the SFR at a research level (unless the new GNEP program also includes basic research components), for investigating other reactor concepts, and for developing crosscutting reactor technology systems. The use of the Generation IV program metrics to compare the high temperature reactors and fast-reactor systems for dual missions—a process heat mission and a fuel cycle flexibility mission—appears to be absent from the current program.

**Recommendation.**—Within the Generation IV program, NE should modestly and reasonably support long-term base technology options other than the VHTR and the SFR, particularly for actinide management, using thermal and fast reactors and appropriate fuels.

**Recommendation.**—Though NE currently focuses on the VHTR for process heat and the SFR for advanced fuel cycles, it should assess the cost-benefit of a single reactor system design to meet both needs.

#### THE ADVANCED FUEL CYCLE INITIATIVE AND GLOBAL NUCLEAR ENERGY PARTNERSHIP PROGRAMS

Since 2002, the United States has been conducting a program of spent fuel reprocessing under the Advanced Fuel Cycle Initiative (AFCI). Then, in February 2006, it announced a change in its nuclear energy programs. Recycling would be developed under a new effort, GNEP, which would incorporate AFCI as one part of its activities. If the recycling R&D program is successful and leads to deployment, GNEP would eventually require the United States to be an active participant in the community of nations that recycle fuel, because one aspect of the GNEP program is that some nations recycle nuclear fuel for other user nations.

The two key stated technical objectives of GNEP are these:

- Develop, demonstrate, and deploy advanced technologies for recycling spent nuclear fuel that do not separate plutonium, with the goal over time of ceasing separation of plutonium and eventually eliminating excess stocks of civilian plutonium and drawing down existing stocks of civilian spent fuel. Such advanced fuel cycle technologies would substantially reduce nuclear waste, simplify its disposition, and help to ensure the need for only one geologic repository in the United States through the end of this century.
- Develop, demonstrate, and deploy advanced reactors that consume transuranic elements from recycled spent fuel.

Three facilities are key components of the GNEP program as currently planned: (1) a nuclear fuel recycling center, or centralized fuel treatment center (CFTC), (2) an advanced sodium-cooled burner reactor (ABR), a fast-neutron reactor, and (3) an advanced fuel cycle facility (AFCF). At the time of the writing of this report, the latest information the committee had was that the baseline separation process was UREX+1a, although some other comparable separation technology, most notably pyroprocessing, may be adopted at a later stage.

All committee members agree that the GNEP program should not go forward and that it should be replaced by a less aggressive research program. A majority of the committee favors fuel cycle and fast reactor research, as was being conducted under AFCI; however, two committee members recommend against such research, as described in Appendix A. The GNEP program is premised on an accelerated deployment strategy that will create significant technical and financial risks, engendered by the premature narrowing of technical options. Moreover, there has been insufficient external input, including independent, thorough peer review of the program. Specifically,

- Domestic waste management, security, and fuel supply needs are not adequate to justify early deployment of commercial-scale reprocessing and fast reactor facilities. In particular, the near-term need for deployment of advanced fuel cycle infrastructure to avoid a second repository for spent fuel is far from clear. Even if a second repository were to be required in the near term, the committee does not believe that GNEP would provide short-term answers.
- The state of knowledge surrounding the technologies required for achieving the goals of GNEP is still at an early stage, at best a stage where one can justify beginning to work at an engineering scale. However, it seems to the committee that DOE has given more weight to schedule than to conservative economics and technology. The committee concludes that the case presented by the promoters of GNEP for an accelerated schedule for commercial construction is un-

wise. In general, the committee believes that the schedule should be guided by technical progress in the program.

- The cost of the GNEP program is acknowledged by the DOE not to be commercially competitive under present circumstances. There is no economic justification to go forward with this program at anything approaching commercial scale. DOE claims that the GNEP is being implemented to save the United States nearly a decade in time and a substantial amount of money. In view of the technical challenges involved, the committee believes that the opposite will likely be true.
- Several fuel cycles could potentially meet the eventual goal of creating a justifiable recycling system. However none of the cycles proposed, including UREX+ and the sodium fast reactor, is at a stage of reliability and understanding that would justify commercial-scale construction at this time. Significant technical problems remain to be solved.
- The qualification of multiply-recycled transuranic fuel is far from reaching a stage of demonstrated reliability. Because of the time required to test the fuel through repeated refabrication cycles, achieving a qualified fuel will take many years.

The committee believes that a research program similar to the original AFCI is worth pursuing.<sup>1</sup> Such a program should be paced by national needs, taking into account economics, technological readiness, national security, energy security, and other considerations. As noted in Chapter 1, however, considerable uncertainty surrounds the technology and policy options that will ultimately satisfy these needs. For this reason, the committee believes that the program described below should be sufficiently robust to provide useful technology options for a wide range of possible outcomes. On the other hand, the program should not commit to the construction of a major demonstration or facility unless there is a clear economic, national security, or environmental policy reason for doing so.

**Recommendation.**—DOE should develop and publish detailed technical and economic analyses to explain and describe UREX-Fla and fast reactor recycle as well as a range of alternatives. An independent peer review group, as recommended in Chapter 6, should review these analyses. DOE should pursue the development of other separation processes until a fully fact-based comparison can be made and a decision taken on which process or processes could be carried to engineering scale. **Recommendation.** DOE should devote more effort to the qualification of recycled fuel, as it poses a major technical challenge.

**Recommendation.**—DOE should compare both the technical and financial risks of such a program with the potential benefits. Such an analysis should undergo an independent, intensive peer review.

**Recommendation.**—DOE should bring together other appropriate divisions of DOE and nations that recycle fuel, because one aspect of the GNEP program is that some nations recycle fuel for other user nations.

**Recommendation.**—DOE should defer the Secretarial decision, now scheduled for 2008, which the committee believes is not credible. Moreover, if it makes this decision in the future, DOE should target construction of new technologies at most at an engineering scale. DOE should commission an independent peer review of the state of knowledge as a prerequisite to any Secretarial decision on future research programs.

#### IDAHO NATIONAL LABORATORY

NE is the lead Program Secretarial Office (PSO) for the Idaho National Laboratory (INL), and as such a significant part of NE's management responsibility and budget is devoted to INL. This responsibility will continue to be a major one for NE, since the management of INL's physical facilities presents two challenges.

First, new or rejuvenated facilities are required to support the new mission and vision for the laboratory. The laboratory envisions that within 10 years, INL will be the preeminent national and international nuclear energy center with synergistic, world-class, multi-program capabilities and partnerships. To achieve its ambitious goals, INL must attract and retain world-class scientists and engineers in a multiplicity of engineering and scientific disciplines. INL must have a budget allowing it to acquire and maintain state-of-the-art facilities and equipment that will be used by researchers of the highest technical competence to lead the development of nuclear power as a valued energy option nationally and internationally.

The second challenge is to maintain the remaining infrastructure in good condition. NE/INL is the landlord for a large, multitenant site in deteriorating condition.

<sup>1</sup> The differing views of two committee members are presented in Appendix A.



DOE employs several metrics to assess the condition of infrastructure. Overall, the INL facilities are rated adequate and the overall utilization, good. However, the backlog of deferred maintenance is high in relation to the value of the assets. In FY 2004 the ratio stood at 11.8 percent for INL's nonprogrammatic assets; the DOE target for this ratio is 2 to 4 percent.

The committee considers that INL is an important facility and provides important capabilities to support NE's mission, which is to use nuclear technology to provide the United States with safe, secure, environmentally responsible and affordable energy. INL has developed a strategic vision and a long-term (10 years) plan on this basis. However, the funding being provided to INL by NE is substantially less than what is needed to fulfill that vision.

Recommendation.—NE should set up and document a process for evaluating alternative approaches for accomplishing NE-sponsored activities, assigning these tasks appropriately, and avoiding duplication.

Recommendation.—NE should set up a formal, high-level working group jointly with the Idaho Operation Office (ID) and INL (Battelle Energy Alliance [BEA]).  
Consideration

